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BACKGROUND FOR INSECT/DISEASE MANAGEMENT PROGRAM

PHASE I FINAL REPORT

Evaluation of Forest Pest Management Programs

Contract No. FS-53-3187-9-30

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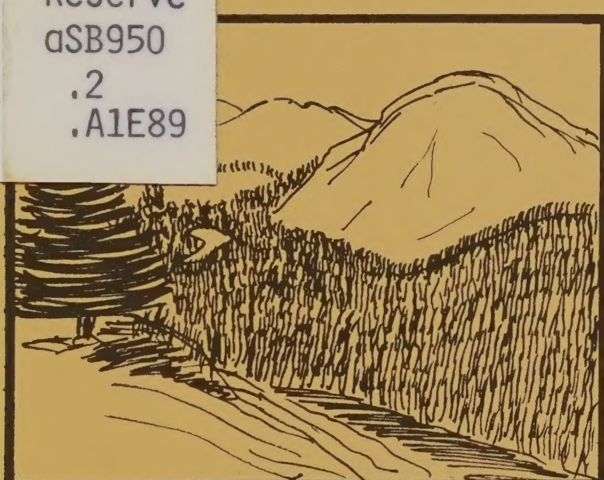

FOR:
U.S.D.A. Forest Service
Policy Analysis Staff

Washington D.C.

BY:

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PREFACE

This report was prepared by the Center for Natural Areas, under contract to the USDA-Forest Service. The Center for Natural Areas (CNA) is a non-profit resource management firm formerly associated with the Smithsonian Institution. The Center employs a multi-disciplinary staff including policy analysts, economists, sociologists, biologists, and an entomologist. Project staff is augmented by consultants with expertise in forest pathology, entomology, and other aspects of insect/disease management.

The purpose of the study is to evaluate thoroughly the USDA-Forest Service's pest management activities by examining pest management policy, the effectiveness of present programs, and by describing options for program adjustments where appropriate. The study is National in scope and examines the three Deputy Areas which are involved in pest management activities: National Forest Systems, State and Private Forestry, and Research.

This report concludes Phase I of the study. The report provides a basic descriptive account of Forest Service insect/disease management programs. The results of this report were used to develop issues and choose case studies for further analysis in Phases II and III. Conclusions stated herein are preliminary and presented for the purpose of summary. A companion report summarizes USDA-Forest Service weed management programs. Both insect/disease and weed management reports will include an economic perspective of Forest Service pest management as an addendum.

When this report was being prepared, the pesticide-use chapter of the Forest Service Manual was being revised and renumbered from Chapter 2140 to Chapter 2150. Simultaneously, a new chapter on integrated pest management was being developed and reviewed as Chapter 2140. These draft Manual revisions have recently been approved and included in the Manual. Thus, references in this report to Chapter 2140 (pesticide-use) should now be made to Chapter 2150 and the draft Chapter 2140 on integrated pest management is no longer a draft.

CNA staff wish to acknowledge the comprehensive and patient assistance provided by the USDA-Forest Service at all levels. Forest Service direction and coordination has been provided by the Policy Analysis staff of the Programs and Legislation Deputy Area. Line and staff officers have been extremely helpful at both the field and national levels. We wish especially to acknowledge assistance from the staffs of Timber Management, Forest Insect and Disease Management, and Forest Insect and Disease Research.

Copies of this report are available from Policy Analysis in the Washington Office of the Forest Service.

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ABBREVIATIONS USED IN TEXT

CANUSA	Canada/USA Spruce Budworms Program
DFTM	Douglas-fir Tussock Moth
EA	Environmental Assessment
EIS	Environmental Impact Statement
EPA	Environmental Protection Agency
ES	Environmental Statement
ESPBRAP	Expanded Southern Pine Beetle Research and Application Program
FEPCA	Federal Environmental Pesticide Control Act
FER	Forest Environment Research
FI&DM	Forest Insect and Disease Management
FI&DR	Forest Insect and Disease Research
FIFRA	Federal Insecticide, Fungicide, and Rodenticide Act
FPL	Forest Products Laboratory
FS	Forest Service
FSM	Forest Service Manual
INT	Intermountain Forest and Range Experiment Station
IPM	Integrated Pest Management
IPMWG	Integrated Pest Management Working Group
MAG	Methods Application Group
NA	Northeastern Area
NAPIAP	National Agricultural Pesticide Impact Assessment Program
NC	North Central Forest Experiment Station
NE	Northeastern Forest Experiment Station
NEPA	National Environmental Policy Act of 1969
NFMA	National Forest Management Act of 1976
NFS	National Forest System
OEQ	Office of Environmental Quality, Department of Agriculture
P&L	Programs and Legislation
PNW	Pacific Northwest Forest and Range Experiment Station
PSW	Pacific Southwest Forest and Range Experiment Station
RM	Rocky Mountain Forest and Range Experiment Station
ROW	Right-of-way
RPA	Forest and Rangeland Renewable Resources Planning Act of 1974
RPAR	Rebuttable Presumption Against Registration
SA	Southeastern Area
SE	Southeastern Forest Experiment Station
SO	Southern Forest Experiment Station
S&PF	State and Private Forestry
TAG	Technical Advisory Group
TMR	Timber Management Research
USDA	United States Department of Agriculture
USDA-DFTMP	USDA-Douglas-fir Tussock Moth Research & Development Program
USDI	United States Department of the Interior
WO	Washington Office (of the Forest Service)

INTRODUCTION

Forest ecosystems cover roughly 750 million acres of the United States, one-third of the nation. Each forest ecosystem is composed of multitudes of organisms which interact, either directly or indirectly, with all other components of the system. Plants from the largest trees to microscopic algae, form the basis of the system on which the numerous species of animals depend for food and shelter. From an ecological perspective, an undisturbed forest is a dynamic, finely tuned system of interacting organisms that each contribute to its overall stability.

From the human perspective, some native and imported organisms reduce the available benefits of the forest resources. These organisms, which are detrimental to the planned management objectives of the forest, are considered "pests". An organism can be characterized as a forest pest only in the context of its impact on the attainment of forest management objectives. Once pests are identified, forest managers must determine how to manage the pest as part of the overall forest management process.

Forest insects and diseases injure trees by causing growth loss, stem deformation, reductions in cone production, mortality, and in a variety of other ways. Nearly two-thirds of the Nation's forests are commercial lands managed for the production of timber and wood products. It is in the best interests of commercial forest managers to include pest management in their activities to decrease the impact of the pests on their stands.

The same organisms that significantly reduce timber production may pose very little threat to the resources of non-commercial forest lands that are managed primarily for wildlife, recreation (including wilderness), or other resources. Conversely, some diseases, such as those predisposing trees to root failure, may be considered hazards in recreation areas but ignored in commercial forests.

Congress directed the USDA-Forest Service to prevent, control, and suppress forest insect and disease outbreaks on forest lands of all ownerships in the Forest Pest Control Act of 1947. Since that time, the Forest Service has taken the lead role in survey and detection activities on all Federally-managed lands and provided assistance to State agencies for evaluating pest problems on non-Federal lands. The USDA-Forest Service also helps finance pest suppression projects on all lands. Research on forest insect and disease problems by the USDA-Forest Service has developed many techniques for surveying, evaluating, preventing, and suppressing forest pest populations.

The advent and subsequent development of pesticides and pesticide technology was and has been eagerly welcomed by forest managers in both the public and private sectors. Forest and agricultural crop managers have become reliant on some pesticides and routinely prescribe their use. Chemical pesticides, when properly used, can provide an effective means of insect and disease suppression. However, pesticides have allowed forest managers to wait until outbreaks occur to suppress the pests, rather than focusing concentration on the prevention of an outbreak. In recent years, opposition to pesticides has increased because of proven and suspected dangers that some pesticides pose to the human and natural environment. Accordingly, forest managers, and especially forest pest managers, have been criticized for reacting to pest outbreaks by applying pesticides over large areas.

USDA-Forest Service must cope with its statutory duty to control forest pest problems in the face of constant criticism for the use of pesticides, even when chemicals may be the most effective and efficient treatment. The policy of the USDA-Forest Service and all Federal agencies is to take an integrated approach to pest problems. USDA-Forest Service policy on integrated pest management (IPM) has been revised recently and now directs forest pest managers to emphasize natural controls and preventive measures and to use pesticides only after a thorough evaluation of social, biological and economic factors justifies their use.

This report describes USDA-Forest Service insect and disease management and research activities. The first chapters analyze the laws (Chapter 1) and policies (Chapter 2) which authorize and direct the programs. Chapter 3 describes Forest Service internal organization and its relationship to the U.S. Department of Agriculture and other government agencies involved in pest management. Chapter 4 discusses pest management as a component of forest management and provides a framework for the following chapters on survey and evaluation (Chapter 5), suppression and prevention (Chapter 6), intensive research, development and implementation programs (Chapter 7). Chapter 8 explains the issues which have developed and which are being used in subsequent phases of this study.

1.0 LAWS

Some of the laws which affect USDA-Forest Service insect and disease programs directly pertain to insect and disease management and others apply only indirectly to pest management through legislation on pesticides, environmental protection, National Forest management, and research (see Table 1-1). This chapter describes pertinent portions of existing insect and disease management legislation, regulations, and major court cases.

1.1 Cooperative Forestry Assistance Act

Current authority for USDA-Forest Service cooperative assistance in insect and disease management is found in the Cooperative Forestry Assistance Act of 1978 (16 U.S.C. 2101). This Act repealed earlier legislation, including the Forest Pest Control Act (FPCA) and the White Pine Blister Rust Control Act (16 U.S.C. 2111 (A)(3)), and consolidated authority for these programs (Sen. Report 95-879, 95th Cong., 2nd Sess., p.1 (1978)).

The Cooperative Forestry Assistance Act parallels its predecessor, the earlier FPCA. The new Act authorized the Forest Service (through the Secretary of USDA) to "prevent, retard, control or suppress incipient, potential, threatening, or emerging insect epidemics and disease infestations affecting trees" (16 U.S.C. 2104 (b)(2)), but unlike the earlier FPCA, the new Act deletes the term "eradicate" (16 U.S.C. 594 (2)). The new Act also recognizes that private landowners may not desire to engage in certain forest management practices "because the benefits of such practices to their ownerships are too small in relation to the cost. However, the benefits to society of these practices might be substantial" (16 U.S.C. 2111 (a)).

Unlike the FPCA which provided only for forest protection through cooperative assistance programs, the Cooperative Forestry Assistance Act has extended protection to wood products, stored wood, wood in use, and individual trees. Individual trees are included because of disease and insect problems in urban areas. Congress perceived these additional categories to require control efforts that go beyond forest lands as commonly defined (Senate Report 95-879, 1978). The new Act also establishes a direct link between cooperative forestry assistance programs and the assessment and program planning processes of the Forest and Rangeland Renewable Resources Planning Act (RPA) (16 U.S.C. 1604) by requiring that the annual evaluation report submitted to Congress for RPA discuss the status of cooperative forestry programs (16 U.S.C. 1606). Federal assistance to these landowners is provided through State foresters who receive direction and funding from the State and Private Forestry branch of the USDA-Forest Service.

TABLE 1-1. Summary of major laws affecting insect and disease programs.

A. Cooperative Forestry Assistance Act of 1978	- Expanded USDA-Forest Service participation to include control of wood product and urban tree pests. - Consolidated several Federal-State-private cooperative programs, including forest insect and disease programs, into one authorizing legislation. - Repealed the Clarke-McNary Act, the White Pine Blister Rust Control Act, and the Forest Pest Control Act.
B. Clarke-McNary Act (1924) (repealed)	- Established Federal-State-private cooperative assistance programs.
C. White Pine Blister Rust Control Act (1940) (repealed)	- Authorized cooperative Federal-State program to eliminate the disease.
D. Forest Pest Control Act (1947) (repealed)	- Created the policies and programs to provide Federal-State-private protection of all forest lands from insect/disease destruction. - Initiated detection and evaluation surveys of all lands.
E. Forest and Rangeland Renewable Resources Planning Act (1974)	- Initiated the RPA planning and assessment process.
F. National Forest Management Act (1976)	- Amended the RPA. - Established guidelines for National Forest System planning and management.

TABLE 1-1, cont.

G. Forest and Rangeland Renewable Resources Research Act	- Amended and repealed the McSweeney-McNary Act which had been the authorizing legislation for forest and range research. - Authorizes research on natural resources management, utilization, protection, and assessment.
H. McSweeney-McNary Act (1928) (repealed)	- Established the Experimental Forestry branch of the USDA-Forest Service. - Provided for funding for pest control research.
I. Federal Insecticide, Fungicide and Rodenticide Act (1947)	- Established registration and and labeling requirements for pesticides. - Amended FIFRA.
J. Federal Environmental Pesticide Control Act (1972)	- Established criteria of no "adverse environmental effects" for registration of pecticides. - Led to the establishment of RPAR.
K. National Environmental Policy Act of 1969	- Requires Federal agencies to prepare environmental impact statements on actions significantly effecting the environment.

The Cooperative Forestry Assistance Act, unlike the FPCA, contains no matching funds requirement. Instead, the new Act requires that the owner of affected land contribute in a manner and in an amount determined by the Secretary (16 U.S.C. 2104 (d)). The USDA-Forest Service is also given explicit authority to allocate funds to other Federal agencies to manage insect and disease problems on lands over which they have jurisdiction (16 U.S.C. 2104 (e)). Cooperative arrangements with other Federal agencies have been formalized in a number of memoranda of agreement, (FSM 1531.01).

1.2 The Forest and Rangeland Renewable Resources Planning Act and the National Forest Management Act

The Forest and Rangeland Renewable Resources Planning Act of 1974 (RPA) as amended by the National Forest Management Act of 1978 (NFMA) (16 U.S.C. 1600-1614) requires the USDA-Forest Service to prepare an assessment and inventory of the renewable natural resources on National Forests. Inventories and assessments must establish a land and resource management program delineating the goals and long-range plans for the National Forests. An evaluation of alternative resource management plans must make up part of the planning process. RPA/NFMA Section 6 (16 U.S.C. 1604) requires the Secretary of Agriculture to develop and maintain resource plans for each Forest, Region, and the entire National Forest System.

Regulations for the development of these long-range plans (44 Fed. Reg. 53983, September 17, 1979, Part IV) require the plans to "guide all natural resource management activities and establish management standards and guidelines for the National Forest System" (36 CFR 219.1 (b)). Although pests are not mentioned in the Act, the regulations do specify that management of "diseases, pests, and other threats" (36 CFR 219.10 (b)) must be addressed in the plans.

Management standards and guidelines set forth in the Act require all management practices to:

> "1. prevent or reduce serious, long-lasting hazards from pests or organisms under the principles of integrated pest management (IPM); and
>
> "2. be monitored and evaluated...<u>to assure that practices protect</u> soil, watershed, fish, wildlife, recreation, and aesthetic values; maintain vegetative productivity; and <u>reduce hazards from insects, disease</u>, weed species, and fire." (36 U.S.C. 219.13 (b) (3) and (5)) (emphasis added).

Thus, as long-range forest plans are developed, insect and disease pests will have to be considered even though they may not be threatening when the plans are being made. Such consideration will call for increased participation of forest entomologists and pathologists from the State and Private Forestry (S&PF) branch in the management of National Forests.

1.3 Forest and Rangeland Renewable Resources Research Act of 1978

The Forest and Rangeland Renewable Resources Research Act of 1978 (16 U.S.C. 1600, 1641-1647) authorizes the Secretary of Agriculture to conduct research on renewable resource management, protection, utilization, and on the environmental effects of resource management. It also authorizes the Secretary to conduct and support research activities which complement the policies and guidelines of the RPA/NFMA.

Insect and disease management research is specifically authorized under the aegis of renewable resource protection. Resource protection research includes "research activities related to protecting vegetation and other forest and rangeland resources...from fires, <u>insects</u>, <u>diseases</u>, noxious plants, animals, air pollutants, and other agents through <u>biological</u>, <u>chemical</u>, and <u>mechanical</u> control methods and systems..." (16 U.S.C. 1642 (3)) (emphasis added). The Act does not specifically mention manual techniques as an area for research. However, pesticide (especially herbicide) opponents often cite manual controls as viable alternatives to using chemicals. Manual methods may be used more frequently in the future than at present.

The Act encourages the Secretary and the Forest Service to: (1) increase cooperation and coordination of research among Federal, State, private industry and university research activities; and (2) ensure that the results of the research are disseminated to the practitioners who can utilize the new knowledge. Moreover, Forest Service and other USDA agencies are authorized and encouraged to provide financial and technical assistance on research deemed essential to their programs. An Office of Technology Transfer has recently been created in the Forest Service to assist in transferring research information and reports to those who can use it.

The Renewable Resources Research Act repealed the McSweeney-McNary Act (16 U.S.C. 581) which had been the authorizing legislation for Forest Service research since 1928.

1.4 Pesticide-use Legislation and Regulations

This section summarizes the requirements and procedures of the Federal Insecticide, Fungicide, and Rodenticide Act (FIFRA), as amended by the Federal Environmental Pesticide Control Act of 1972 (FEPCA) (7 U.S.C. 135), and then discusses in more detail those aspects of the Acts which have proven to be of particular relevance to USDA-Forest Service insect and disease programs.

FIFRA delegates the major responsibility for regulating chemical pesticides to the Environmental Protection Agency (EPA). The 1975 amendments to the original Act expand the definition of "pesticide" to include all substances intended to prevent, destroy, repel or mitigate any pest, whether vegetation or animal (7 U.S.C. 136(w)). Some of these responsibilities include the formulation of standards for the registration, suspension, and cancellation of pesticides.

Registration

The central provision of FIFRA is the requirement that all "economic poisons" must be registered with EPA before they may be distributed, sold, or offered for sale (7 U.S.C. 135a). Economic poisons are defined as:

> "any substance or mixture of substances intended for preventing, destroying, repelling, or mitigating any insects, rodents, nematodes, fungi, weeds and other forms of plant or animal life...which the Administrator shall declare to be a pest, and any substance or mixture of substances intended for use as a plant regulator, defoliant or desiccant." (7 U.S.C. 135 (a))

The Administrator of EPA may declare any form of plant or animal life which is injurious to health or environment a pest (7 U.S.C. 136w(c)(1)).

FIFRA goes into considerable detail concerning registration procedures, the criteria for approval, and the consequences of disapproval (7 U.S.C. 136). The Senate Commerce Committee, in its desire for "the EPA to make a full weighing of competing interests in making its determinations", required the applicant for registration, i.e., a chemical company or other interested party, to prove that the use of the chemical for the specified purposes and by the specified methods is safe and poses no "unreasonable adverse effects" on the environment. The process includes consideration of the economic, social, and environmental costs and benefits of the pesticide. Any "adverse effect ought not to be tolerated unless there are overriding benefits from the use of a pesticide" (Senate Report 92-970, 92nd Cong., 2nd Sess., 11(1972)).

A registered pesticide may be classified for general use, restricted use, or both (7 U.S.C. 136a(d)). A restricted use pesticide, i.e., one which is considered to have a high potential for personal or environmental risk, can be applied only under the supervision of a certified applicator or subject to other restriction.

Suspension and Cancellation

Basic criteria governing registration also apply to cancellation proceedings. If it appears that a pesticide "when used in accordance with widespread and commonly recognized practice, generally causes unreasonable adverse effects on the environment" (7 U.S.C. 136d(b)), the Administrator may issue a notice of intent to cancel the registration of a pesticide, or change its classification. The key determination is whether continued use may lead to "unreasonable adverse effect on the environment."

An option open to the Administrator in dealing with suspect registered pesticides is suspension. The registration of a pesticide may be immediately suspended and, as a result, its sale and use prohibited, if the Administrator determines "that action is necessary to prevent imminent hazard during the time required for cancellation or change in classification proceedings (7 U.S.C. 136d(c)(11)).

The term "imminent hazard" as defined by FIFRA means "a situation which exists when the continued use of a pesticide...would be likely to result in unreasonable adverse effects on the environment or will involve unreasonable hazard to the survival of a species declared endangered or threatened pursuant to the Endangered Species Act" (7 U.S.C. 136(1)). The most important element of "imminent hazard" is a "serious threat to public health" Environmental Defense Fund, Inc. v. Ruckleshaus, 439 F.2d584, 597 (D.C. Cir. 1971). A hazard may be "imminent" even though its impact may not be apparent for many years.

The stringent procedures set forth by FIFRA, requiring the EPA to determine "imminent hazard(s)" and "unreasonable adverse effect(s) on the environment" both prior to the registration of and during the use of, pesticides, have been interpreted by some pesticide users as proof that registered pesticides used according to the label directions and restrictions are safe for use and pose no known health or environmental problems even though public sentiment may run high against the chemical. Since many pesticides now in use were registered prior to the development of current EPA standards and modern analytical techniques, such reliance may be misguiding. One court has determined that a pesticide project for which an EIS is prepared must include a discussion of known risks to human health as part of the EIS (Citizens Against Toxic Sprays v. Bergland, et al., 428 F. Supp. 908, 927 (D. Ct. Or. 1977)).

EPA review of some existing pesticides may bring about further restrictions.

Exemptions to Registration

Several major exemptions to the registration requirements are: (1) pesticide use pursuant to an experimental use permit; (2) use by State or Federal agencies after the Administrator determines that emergency conditions exist; or (3) use to meet special local needs even though criteria for Federal registration are not met (7 U.S.C. 136).

The EPA has issued regulations clarifying the circumstances in which emergency exemptions may be granted to Federal agencies. These exemptions extend to unregistered pesticides, even those for which registration has been denied. According to these regulations, an emergency will be deemed to exist when:

> "(1) a pest outbreak has, or is about to occur, and no pesticide registered for the particular use or alternative method of control is currently available to eradicate or control the pest;
>
> (2) a significant, economic or health problem will occur without the use of the pesticides; or
>
> (3) the time available from discovery or prediction of the pest outbreak is insufficient for the pesticide to be registered for the particular use" (40 C.F.R. 166).

Exemptions falling into the first category may only be granted for a specific time period, in no event to exceed one year. Perhaps, the best known example of such an exemption was that granted the USDA-Forest Service in 1974 to use DDT to control the Douglas-fir tussock moth (39 Fed. Reg. 8377 (1974)). That exemption was granted contingent on Forest Service attempts to develop a suitable alternative.

USDA-EPA Cooperation

Several proposals which would have required the concurrence of the Secretary of Agriculture on decisions made by EPA regarding pesticide registrations, classifications, and cancellations, as well as proposed and final regulations, were rejected by Congress (H. R. Report 95-497, 94th Cong., 1st Sess., 33 (1975)). However, the strong interest of the Department of Agriculture, which had regulated pesticides prior to EPA's establishment in 1970, was recognized by Congress, which provided an elaborate consultation mechanism.

At least 60 days prior to signing a proposed regulation and 30 days prior to signing a final regulation, the Administrator of EPA must provide the Secretary of Agriculture with a review copy (7 U.S.C. 136w(a))1)). Timely comments by the Secretary and the responses of the Administrator must be published in the Federal Register along with the text of the regulations. Similarly, the Administrator must provide the Secretary with a copy of any notice of intent to cancel the registration of a pesticide and an analysis of the impact of the proposed action on the agricultural economy at least 60 days prior to sending such notice to the registrant or making it public. The comments of the Secretary are also published in the Federal Register.

Further cooperative arrangements between USDA and EPA are specified in two memoranda of understanding between the two agencies (Memorandum of Understanding between USDA and EPA, December 2, 1976 and October, 1977). These agreements are discussed in Section 3.3 of this report.

1.5 National Environmental Policy Act

The National Environment Policy Act of 1969 (NEPA) (42 U.S.C. 4321, 4331-4335, 4341-4347) affects all USDA-Forest Service management activities, including insect and disease management programs, by requiring that environmental assessments be conducted by the agency to determine the effect of the management activity on the environment. Actions "significantly affecting the quality of the human environment" require environmental impact statements (EIS's) to show the effects, alternatives, and mitigating procedures (42 U.S.C. 4332 (c)). If an EIS inadequately considers available alternatives or falls short in weighing relevant scientific evidence, such a failure can provide citizens groups with sufficient ammunition to enjoin pesticide applications.

USDA-Forest Service activities are reviewed for their environmental impact through the "NEPA Process" as described in section 1950 of the Forest Service Manual.

1.6 Court Cases

Court cases concerning Forest Service pest management activities divide into two groups: 1) those based on common law negligence, trespass and strict liability theories and 2) those concerning NEPA requirements for environmental impact statements.

A majority of litigation concerning pesticides falls within the first group where claimants seek compensation for injury to crops, people, or other living things (often honey bees and vegetable gardens) due to the negligence of the pesticide applicator in applying the pesticide (Rogers, 1977, and cases cited therein).

The most common cases deal with the drift of aerially applied pesticides onto adjacent lands. In pesticide negligence cases, courts are often satisfied with virtually no proof of fault of the applicator (Rogers, 1977).

NEPA Requirements Cases

Although much of the case law in this area has specifically related to herbicide use, it also applies to insecticides and other pesticides. NEPA case law requires the USDA-Forest Service to consider the environmental effects of its activities even though necessary scientific inquiry concerning controversial pesticides must be conducted by EPA (Citizens Against Toxic Sprays, Inc. v. Bergland, 428 F. Supp. 908, 927 (D. Ct.Or. 1977)). An acting agency must perform its own environmental assessments even though another agency is authorized to develop and enforce environmental standards (Calvert Cliffs Coordination Committee v. Atomic Energy Commission, 449 F.2nd 1109, 1123, cert. denied 404 U.S. 942 (1972)). Although a particular project may use substances registered under FIFRA, such registration does not exempt that project from the requirements of NEPA (Environmental Defense Fund, Inc. v. Hardin, 325 F. Suppl 1401, 1407 (D.D.C. 1971)).

As a result, EIS's prepared for USDA-Forest Service programs which use pesticides must assess the potential environmental consequences of the application of those pesticides. Remote or speculative consequences need not be discussed in detail, but it is necessary that all potential environmental effects be mentioned. The EIS must indicate the extent to which environmental effects are uncertain or unknown (Citizens Against Toxic Sprays Inc. v. Bergland, supra., at 924, citing Sierra Club v. Froehlke, 534 F.sd 1289, 1296 (8th Cir. 1976)).

Furthermore, where scientists disagree about the possible adverse environmental effects, the EIS must inform decision makers "of the full range of responsible opinion." Similarly, the discussion of alternatives in the EIS must go beyond mere assertions and provide sufficient data and reasoning to enable a reader to evaluate the analysis and conclusions and to comment on the EIS. For example, in Citizens Against Toxic Sprays, an EIS concerning the use of 2,4,5-T (a herbicide) by the USDA-Forest Service in Region 6 was determined to be inadequate due to its failure to discuss: (1) the extreme toxicity of TCDD; (2) the potential impacts of application on agricultural crops on adjacent private lands; (3) the scientists' disagreement concerning the hazards of TCDD; (4) the controversy over the use effects of Agent Orange (which contains TCDD) in Viet Nam; or (5) EPA administrative proceedings then taking place against the registration of 2,4,5-T. Injunctive relief was therefore granted with respect to TCDD-related hazards until such time as the inadequacies of the EIS are corrected. It

should be noted that the _Citizens Against Toxic Sprays_ case is currently on appeal to the North Circuit Court of Appeals (R. Fullerton 1979, personal communication).

SUMMARY

Congress has long recognized the need for reducing damages caused by forest insect and disease pests. Early laws dating back to 1924 authorized the USDA-Forest Service to cooperate with, and provide financial assistance to, state and private forest land owners with pest problems. The Cooperative Forestry Assistance Act of 1978 is the most recent example of a law dealing with pest management; in substance it closely parallels the philosophy of the very legislation it replaced. In addition to legislation authorizing the Forest Service pest management programs, various other laws and regulations greatly influence forest pest programs.

The National Forest management standards and guidelines which were developed to comply with the Forest and Rangeland Renewable Resources Planning Act (RPA), as amended by the National Forest Management Act (NFMA), require unit plans to include ways to reduce hazards from insects and diseases. All forest management practices are to be conducted through techniques which prevent or reduce potential pest problems by the principles of IPM. Thus, regulatory requirements for IPM on National Forest System lands through RPA/NFMA have been added to existing administrative directives on IPM.

Litigation about pest management programs most frequently deals with pesticides. The courts have found that pesticide applicators are responsible for damage to crops, people, or other living things when the pesticides drift onto adjacent property. Forest Service pesticide programs have been challenged under NEPA. The courts have ruled that the Forest Service must consider the environmental consequences of the pesticide. Furthermore, when there is disagreement in the scientific community about the environmental effects, the EIS should discuss the areas of disagreement.

[illegible] practices [illegible]

[illegible] proactive [illegible]

[illegible] respectively [illegible]

[illegible] findings that [illegible]

[illegible] service pesticide [illegible]

[illegible]

[illegible] registration [illegible]

[illegible] potential impacts [illegible]

[illegible] (1) the [illegible] registration [illegible]

[illegible] II-1 [illegible]

2.0 POLICIES

Insect and disease management and research policies are found in several chapters of the Forest Service Manual (FSM). This objective is stated in the Forest Insect and Disease Management (FI&DM) chapter of the Manual and applies to Forest Insect and Disease Research (FI&DR) activities, integrated pest management (IPM), and timber management. The objective of all insect and disease pest activities is:

> "to reduce damage and loss caused by insects and diseases on all forest lands to levels commensurate with forest resource and other environmental values involved." (FSM 3402)

This chapter examines the USDA-Forest Service insect and disease policies as they are stated in the Manual and other directives. Three chapters of the Manual; Forest Insect and Disease Management (FSM 3400), Pesticide-Use Management (FSM 2140, draft FSM 2150), and Integrated Pest Management (draft FSM 2140), comprise the basis for insect and disease management policies. FI&DR and environmental planning policies are also analyzed.

2.1 Forest Insect and Disease Management

Like most other policies stated in the Manual, the FI&DM policy is set forth as a directive in order to allow for flexibility in field implementation.

> "Forest Service policy is to protect and preserve the forest resources of the Nation against destructive forest *insects and diseases by preventing or suppressing problem populations by methods that will restore, maintain, or enhance the quality of the environment" (FSM 3403).

A number of different activities are involved in such protection and preservation. The remainder of chapter 3400 provides direction as to the types of activities needed to conform with the above policy.

*Note: Forest Service responsibility for insect and disease management is limited to forests, forest products, nurseries, seed orchards, and urban trees. The FI&DM cooperates with other agencies having responsibility for other insect and disease pest problems. For instance, the Animal and Plant Health Inspection Service (APHIS) is responsible for controlling range and forage insect problems even if the pests are on National Forest lands.

Little difference exists between the policy statement of FSM 3403 and the objective set forth in FSM 3402. Both are stated in general terms to allow for professional interpretation by project managers.

Prevention

Prevention of pest epidemics is an important component of IPM and forest management. FI&DM policy on prevention is:

> "The Forest Service will stimulate, encourage, and facilitate the use of effective prevention measures as the first line of defense against damaging insects and diseases." FSM 3403.2

Even though the policy looks to prevention "as the first line of defense," there are no funds allocated to implement preventative practices. The FI&DM role is to provide technical assistance to land managers involved in prevention measures, through training sessions, review of management plans, and demonstration projects. FI&DM does not have direct land management responsibilities. Accordingly, FI&DM funds may not be used to finance measures such as thinning to make forest stands resistant to insect or disease attack, or regular maintenance application of pesticides, as in seed orchards (FSM 3451.1). Plans are currently being developed to request appropriations for FI&DM prevention work.

Detection and Evaluation

FI&DM also has responsibility for forest insect and disease detection surveys and biological evaluations. Detection surveys are conducted to allow early discovery of potential pest threats (FSM 3403.2 and 3420.3). Evaluations, both ecological and socio-economic, are made in areas exhibiting problems or in highly susceptible forests where action is needed. An evaluation includes alternative management actions and the expected pest consequences from each (FSM 3403.4).

Suppression

Forest Service policy on suppression is to:

> "use all appropriate silvicultural, biological, and chemical tools to suppress insect and diseases that are causing, or may cause unacceptable losses. All suppression will be by effective means and result in the least potential hazard to man, domestic animals, and other non-target components of the environment." FSM 3403.5

This policy clearly indicates that effectiveness and potential environmental hazards are key aspects in selecting the proper suppression tool. Chemical sprays can only be used after all non-chemical alternative tools have been considered (FSM 3442.21) and found inadequate to suppress the pest successfully. For many problem insects, the only known effective suppression technique is to spray the infested area with chemicals. Many people might not feel that chemicals serve as the suppression tool that minimizes potential hazards to man or the environment. In these cases, it can be difficult to meet both aspects of this policy. As a result of increasing concern over the environmental effects of pesticides and new research on pest population dynamics, FI&DM policies are changing to address the concepts of IPM.

2.2 Integrated Pest Management

Administrative Directives

On December 12, 1977, Secretary of Agriculture Bergland issued Secretary's Memorandum Number 1929 which states:

> "It is the policy of the U. S. Department of Agriculture to develop, practice, and encourage the use of integrated pest management methods, systems, and strategies that are practical, effective, and energy-efficient." USDA Secretary's Memo. 1929

Since the declaration of this policy, the USDA-Forest Service and other agencies within the Department have been involved in revising their manuals and methods of operation. The Forest Service Manual was revised in February 1979, and is presently being revised again to establish guidelines for agency compliance with the IPM policies of the Department.

President Carter, in his Environmental Message of August 2, 1979, emphasized that IPM should be encouraged in all Federal research and operational programs. At that time, he directed all Federal agencies to: (1) review all pest management activities to assess their compliance with IPM; (2) modify existing programs to conform to IPM strategies; and (3) report on the review and modifications to an interagency IPM Coordinating Committee by June 30, 1980 (Council on Environmental Quality 1979). The Office of Environmental Quality in the Department of Agriculture has formed a committee which is currently reviewing the Department's policies and programs.

Forest Service Manual

Current USDA-Forest Service policy which reflects these administrative directives on IPM is found in Section 2140 of the Manual; Pesticide-use Management:

> "It is Forest Service policy to develop, practice, and encourage the use of integrated pest management methods, systems, and strategies which provide adequate protection against significant pests with the least hazard to man, his possessions, wildlife, and the natural environment. Natural controls and selective measures are to be adopted as rapidly as possible. IPM may include the use of chemical pesticides." FSM 2140.3

A new section of the Manual is currently being drafted to elaborate on IPM and further define the directives. Draft FSM 2140 (Integrated Pest Management) is scheduled for distribution in December, 1979 (Pesticide-Use Management will be changed to Pesticide-Use Management and Coordination (FSM 2150) when the IPM section is published.). The draft policy of the USDA-Forest Service dealing with IPM reads as follows:

> "Forest Service integrated pest management policy is to develop, practice, and encourage the use of IPM methods, systems, and strategies which provide protection of forest resources with the least hazard to man, his possessions, wildlife, fish, and the environment. This includes: the use of natural controls and other selective methods that will reduce reliance on chemicals; the management of forest resources in a manner that is not conducive to the development and perpetuation of pest problems; the prudent timing of applications; and the demonstration of effective and workable IPM practices and strategies and encouragement of their acceptance." draft FSM 2140.3

A notable difference between the two policies is that the new IPM policy provides direction to reduce reliance on pesticides and to manage all of the forest resources so that pest problems will be prevented. The new policy indicates a shift in research as well as management activities. The new IPM policy also requires the land managers to become more involved in planning the timing of their activities to reduce potential threats from pests. IPM is also required to be addressed in forest and regional plans by the National Forest System Land and Resource Management Planning standards and guidelines (44 Fed. Reg. 181: Pt. IV, Sept. 17, 1979)

Environmental and economic aspects of pest management are also addressed in the draft IPM objective.

> "To insure optimal pest management with respect to environmental concerns, biological effectiveness, and economic efficiency while achieving resource management objectives." draft FSM 2140.2,

The terms "optimal pest management," "biological effectiveness," and "economic efficiency" are not precisely defined in draft section FSM 2140.5, section 2140. Therefore, this objective of IPM seems as general as the FI&DM objectives stated in FSM 3402. The definition of IPM, "a comprehensive systems approach to achieving pest control in an environmentally acceptable manner" (draft FSM 2140.5), seems vague when compared to insect and disease management guidelines in Chapter 3400 of the current Manual. Whereas Chapter 3400 goes into considerable detail as to how the policy for Forest Insect and Disease Management is to be implemented, such detailed descriptions are not included in the draft Section 2140.

Surveys and interviews conducted for this project indicate that many professionals within the USDA-Forest Service are finding it difficult to discern the differences between the objectives of IPM and the objectives of pest management activities prior to the advent of IPM. However, these responses were received prior to circulation of draft FSM 2140. Comparison of the "old" (being the June, 1978, amendments to FSM 3400) and "new" (the IPM section 2140 which is still in draft) policies and objectives indicates that there may still be confusion in this area. The concepts presented in the FI&DM and pesticide-use sections of the current Manual seem to correspond to those in IPM. In spite of these similarities, many forest managers in practice have emphasized suppression of pest outbreaks rather than early prevention of problems (Miller and Committee, 1975). Draft FSM 2140 elaborates on IPM and further establishes that the concept is to be employed in all forest management activities.

2.3 Pesticide-Use Policies

The policies governing pesticide use are found in section 2140 of the FSM. Selected USDA-Forest Service policies relevant to insect/disease management with regard to pesticides are as follows:

> "#1. Pesticides may be recommended and used in operational projects only after consideration of alternatives--based on competent analyses of effectiveness, specificity, environmental impacts, and benefit-cost--clearly demonstrates that the use of the

pesticide is essential to meet management goals.

"#2. The requirements of Title I of the National Environmental Policy Act must be met...

"#3. Only pesticides registered by the Environmental Protection Agency...may be used, except as otherwise provided in regulations, orders, or permits issued by EPA.

"#5. Where endangered or threatened animal or plant species habitat is involved, pesticides may be used only after it is determined...that such use will adversely affect neither the species nor its critical habitat.

"#6. Pesticides will not be used in Wilderness areas; (except)...where necessary to prevent the loss of significant aspects of the wilderness area or to prevent significant losses to resource values on public or private lands bordering the wilderness. The use of chemicals for controlling outbreaks of insects and diseases in a designated wilderness must be approved by the Assistant Secretary for Natural Resources and Environment.

"#7. Pesticide application and use must be controlled in a manner that ensures adequate safety...Treated areas will be posted with appropriate signs indicating the name of the material used and date of application to ensure that potential forest users...are informed of possible exposure to pesticides. In addition, the project officer will confirm that all persons in or near the treatment areas are notified.

"#8. Pesticides and pesticide containers will be transported, stored, and disposed of in accordance with Federal, State, and local news and regulations.

"#10. When applying pesticides in sensitive situations, appropriate environmental monitoring will be carried out to determine amount of drift, if any, into nontarget areas and to detect unanticipated nontarget effects.

"#12. Special attention will be given to all restricted-use pesticide handling and use precautions.

"#13. The Forest Service shall conduct and support research to develop and to evaluate the effectiveness and environmental safety of pest management technology...and to effectively transfer this technology to minimize costs and adverse environmental and health impacts." (FSM 2140.3(1)-(14)).

These policies became effective in February, 1979 and provide the basis for the policies in the draft Pesticide-Use Management and Coordination Section 2150, which is currently being reviewed. These policies recognize that pesticides can be an important tool of the forest manager but that they should not be used unless they are essential to meet management goals. When pesticides are found to be needed, they should be used with extreme care for personal safety and environmental effects.

2.4 Forest Insect and Disease Research

Forest Insect and Disease Research (FI&DR) policies are found in three chapters of the Manual: 1) FSM 4510 which provides general goals and directions to FI&DR; 2) FSM 4060 which describes the objectives and organizations of the Research Deputy Area; and 3) draft FSM 2140 which provides direction to the Research Deputy Area for IPM.

Forest Insect and Disease Research goals are to provide technology and new knowledge that can be used to decrease forest losses resulting from destructive insects and diseases. Specific studies to be conducted include: (1) determining methodologies for measuring and evaluating the ecological and socioeconomic impacts of forest pests; (2) improving detection and assessment procedures; (3) developing pest management and control techniques and strategies that satisfy environmental, economic, and efficacy criteria (FSM 4510). Research on the above aspects of pest problems could constitute an IPM approach to research but IPM is not specifically mentioned. One essential component of IPM - prevention - is also not specifically mentioned.

Overall Research Deputy Area policies call for the Forest Service to: (1) carry on high priority research for the management, protection, and utilization of timber, water, range forage, wildlife, and recreation; (2) conduct research only within approved Research units; (3) disseminate results of the research to interested public and private agencies and individuals; and (4) assist users in applying research results (FSM 4060.3). Research units are to work closely with the National Forest System and State and Private Forestry Deputy Areas when determining what research is needed and ensuring that it can be implemented.

FI&DR and other functional Research staffs are to conduct their pest management research activities within the context of IPM. The draft IPM Manual revision states:

> "It is Forest Service policy to conduct and support research to develop and evaluate effectiveness and environmental safety of new pest management technology including new and improved silvicultural techniques, pesticide formulations, applications, and monitoring techniques, and alternative pest management methods and tools" draft FSM 2140.3.

By including silviculture as a type of IPM research, the Manual revision indicates that forest pest research activities should take a holistic approach to managing forest pests. The Accelerated Pest Research and Development programs did this by bringing together experts from many areas of expertise to study four insect problems in an IPM context.

2.4 Forest Service NEPA Process

In order to comply with the National Environmental Policy Act of 1969 (NEPA), the Forest Service has developed a set of policies and guidelines to assure that an environmental assessment (EA) is part of all planning and decision-making activities. Assessments are conducted by interdisciplinary teams according to the directives found in FSM 1950 - the Forest Service NEPA Process. Preparation of an EA and activities which result from it, such as environmental statements (ES's) make up the "process."

The NEPA process is a multi-staged systematic approach which formalizes Forest Service methodology. It adheres to the process found in FSM 1952 which includes the following steps:

1. Identify issues, concerns, and the need for a decision.
2. Select criteria and standards on which to base the assessment.
3. Gather related information on present and future conditions.
4. Formulate a reasonable range of alternatives to address the issues and concerns identified in Step 1.
5. Analyze the direct, indirect, and cumulative effects of implementing each alternative.
6. Evaluate current and future outputs and changes of each alternative.
7. Identify the Forest Service preferred alternative based on the analysis and evaluation of Steps 5 and 6.

Upon completion of these steps, a decision is made and documented in an environmental assessment report (EAR) as to what additional environmental analysis and decision-making activities are needed to complete the NEPA process.

An environmental assessment yields one of two decisions (Figure 2-1). If the EA discloses that the proposed action will have no significant impact on the environment, then a record of that decision is filed in the EAR. On the other hand, if the assessment discloses that the proposed activity is a major Federal action significantly affecting the environment, then an ES is prepared. ES's are detailed reports on the proposed activity and its effects on the environment. The significance of preparing adequate ES's cannot be overestimated because through NEPA their inadequacy can serve as a basis for court challenges to pest management and other Forest Service activities.

SUMMARY

Three basic policy objectives direct forest insect and disease programs in the USDA-Forest Service which are:

1) to protect and preserve the Nation's forest resources from insect and disease hazards (as stated in the FI&DM section of the Manual);

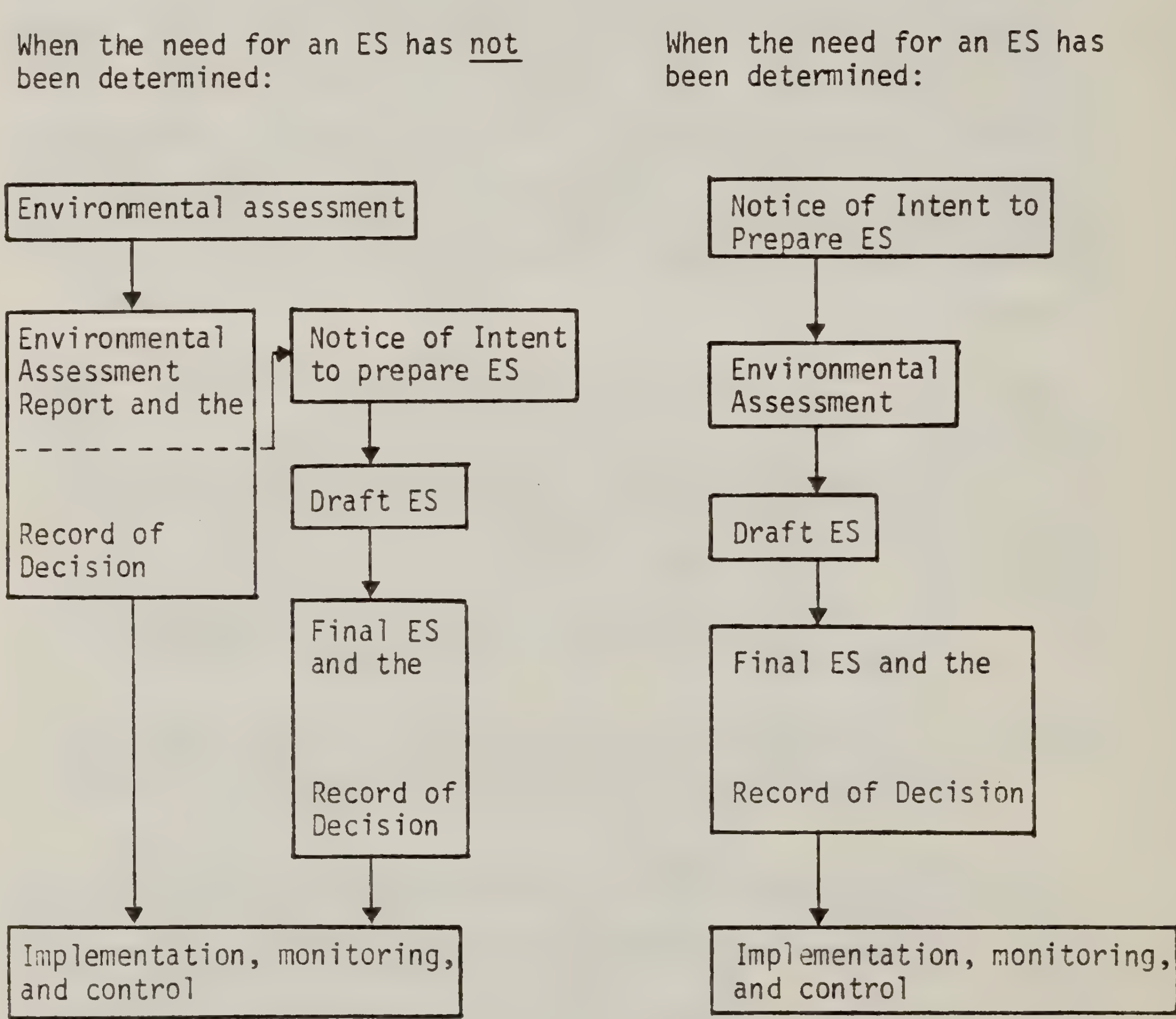
2) to use IPM strategies and methods to accomplish policy 1 above (as stated in the draft IPM Manual section); and

3) to conduct research on methodologies and systems (IPM and otherwise) that can be employed to meet the objectives of policy 1 above (FI&DR Manual section).

The actual policy statements in the Manual from which these generalizations are taken contain qualifying phrases to assure that activities are conducted in an environmentally safe, economically efficient, and biologically effective manner. Conformation to the qualifying statements in these policies requires personal interpretation of phrases which are difficult to define precisely, thus requiring professional judgement. These overall policies are complemented by further directives on specific aspects of the FI&DM and FI&DR programs, as well as other policies dealing with environmental and pesticide coordination.

Pesticides are an important component of IPM strategies. Accordingly, Forest Service policies concerning pesticides (FSM 2140, draft FSM 2150, FSM 4510) are significant to forest pest management and research programs. The principles of the pesticide policies are that they should be used and recomended <u>only</u> when

FIGURE 2-1. The NEPA Process (FSM 1950).



other viable alternatives do not exist and when pesticides are essential to meet management goals. The policy clearly indicates that non-pesticide methods should be used wherever they are feasible. When it is determined that pesticides are essential, however, the policies require that they be used in accordance with appropriate safety and environmental regulations.

3.0 ORGANIZATION AND ADMINISTRATION

3.1 Forest Service Internal Organization

The Forest Service organizational structure is made up of five branches (called Deputy Areas) with three to four distinct levels of authority in each (see Figure 3-1). Of the five Deputy Areas, three - the National Forest System (NFS), Research, and State and Private Forestry (S&PF) - are involved in insect and disease activities. The organizational hierarchies within each of the branches are similar with regard to responsibilities and authorities.

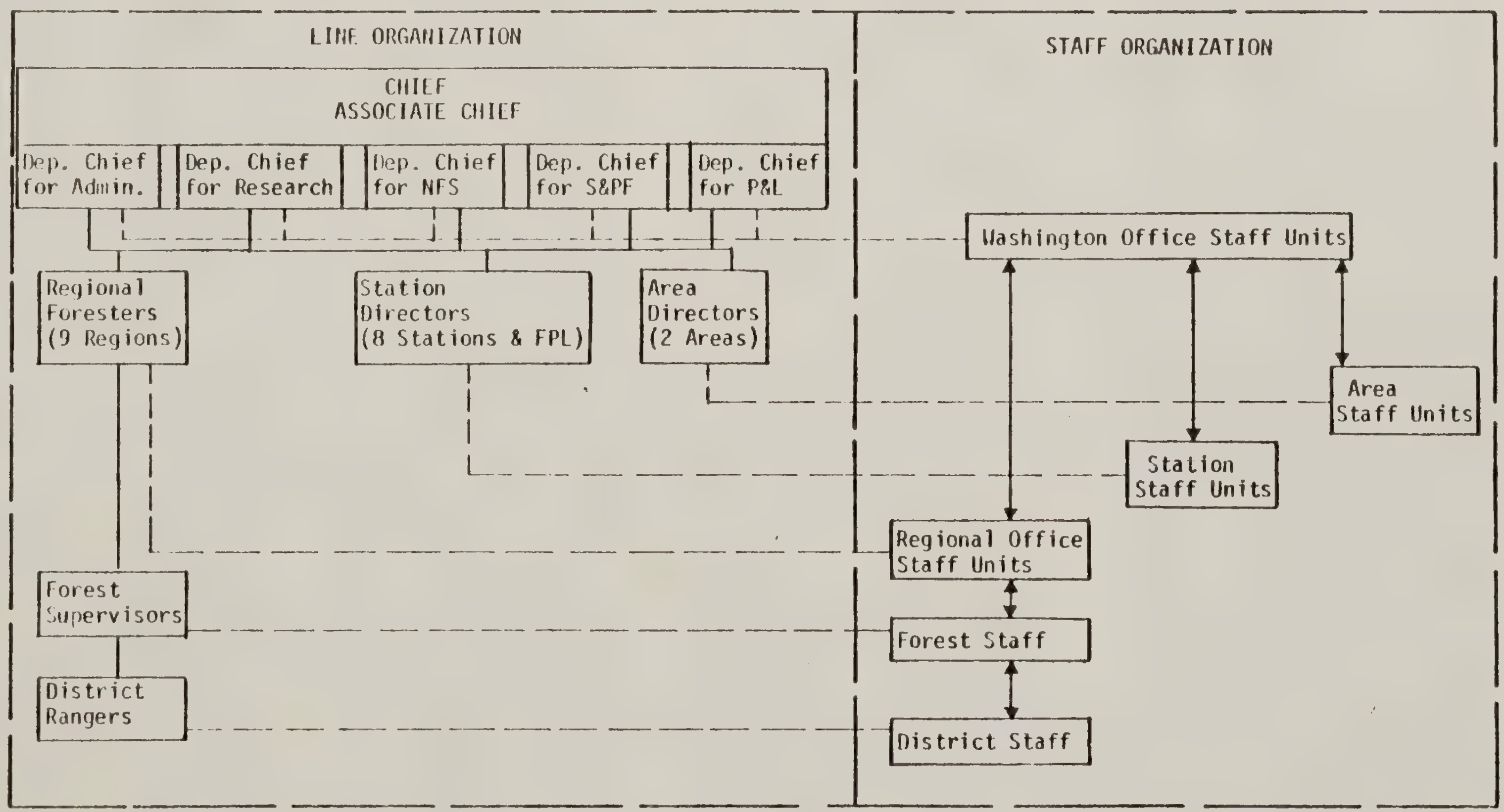
At the top of the organizational structure is the Chief, who is ultimately responsible for all functions and activities of the agency. Below the Chief on the organizational chart is the second level of line authorities: Regional Foresters of the NFS; Experiment Station Directors of the Research Deputy Area; and S&PF Area Directors. Making up the third level of line authority are the Forest Supervisors (NFS) and Research Project Leaders. The District Rangers form the base of the administrative pyramid of the NFS. Except for Rangers and some Forest offices, a Deputy position may exist which reports to the line officer and has specifically delegated line authority.

The USDA-Forest Service, decentralizes authority and responsibility. The District Rangers are responsible for the actual planning and implementation of land and resource management projects. The projects which the Rangers carry out are reviewed, approved and recommended by the three upper organizational levels. The Forest Supervisors approve, recommend, and inspect the activities in the Districts. The Regional Foresters advise, approve, and inspect the Forests, and the Chief and the Washington Office staff do the same for the Regions.

Similar situations exist in both S&PF and Research Deputy Areas, although the staffs of these are not as large. The Research Deputy Area line authority begins with the Project Leader and passes to the Experiment Station Director and the Chief. Deputies to the Chief, Experiment Station Directors, and Assistants to the Area Directors, are often delegated specific line authorities.

Washington Office staff supports the Chief and Deputies by advising them on policy, program direction, and budget matters. Experts on all aspects of agency activities make up the Washington Office units. Even though this staff lacks the line authority to assure implementation of programs, the individuals in the Washington Office maintain considerable leverage over Regional, Area, Forest, and Experiment Station programs by virtue of their working

FIGURE 3-1. Roles and Line-Staff Relationships (Source: FSM 1206).



at the top levels of the organization (Robinson 1975). The level of influence which the Washington Office staff exerts over field staff and activities varies with individuals and positions throughout the agency.

Forest Insect and Disease Management (FI&DM)

FI&DM is part of the S&PF Deputy Area. S&PF's organization differs in the East from the West. In the West, (Regions 1,2,3,4,5,6, and 10), S&PF is part of the Regional Foresters' Staff. The head of S&PF in these Regions is the Deputy Regional Forester for S&PF. In the East, (Regions 8 and 9), S&PF is not directly part of the Regional Foresters' staff. Instead, there are two areas--Northeastern and Southeastern (corresponding approximately to Regions 9 and 8, respectively)- each headed by an Area Director. Area Directors are line officers for S&PF staffs.

The different structures of S&PF in the East and West reflect the ownership patterns of forest lands. In the West, most forest land is publicly managed by the USDA-Forest Service, the Bureau of Land Management, or other public agencies. State and private lands are significant for producing wood products but are small in comparison to Federal lands. The opposite ownership patterns characterize the East, where most forest lands are privately held. S&PF maintains a wide variety of incentive and management assistance programs to aid forest landowners, primarily in the East, to help insure adequate supplies of forest resources and products from the relatively small acreage in public ownership.

FI&DM staffs bear the primary responsibility to protect forests and forest resources from insect and disease hazards. They do so through prevention, detection, evaluation, and suppression of existing and potential pest outbreaks. Detection surveys, biological evaluations, and technical assistance on pest problems are routine procedures of these groups.

The Methods Application Group (MAG), a specialized FI&DM unit located in Davis, California, consists of specialists in data management, spray and survey technology. MAG reports directly to the Washington Office FI&DM staff to facilitate its inter-regional responsibilities.

FI&DM staff responsibility also includes providing expertise and technical assistance for forest pesticides (including herbicides) to the USDA-Forest Service, other Federal agencies, states, and private forest landowners. In the Washington and Regional Offices, FI&DM personnel manage the Integrated Pest Management Working Groups (IPMWG) (formerly the Pesticide-Use Coordinating Committees) and serve on a number of pest management and pesticide task forces.

The Washington Office-IPMWG is headed by the Deputy Chief of S&PF and serves as a coordinating committee to address the policy aspects of IPM and pesticide-use management. The WO group, as a unit, does not authorize or approve individual projects, whereas Regional IPMWG's are often delegated the responsibility for approving projects by the Regional Forester.

Forest Insect and Disease Research

The Research Deputy Area follows the line/staff organization structure of the other deputy areas. Authority descends from the Chief to both the Deputy Chief for Research and the eight Station Directors. The Deputy Chief for Research is responsible for coordinating, planning, and directing all Research programs. There are seven functional Research staffs in the Washington Office which advise the Deputy Chief. Forest Insect and Disease Research is the staff which has entomology, pathology, and pesticide expertise.

Organization of the experiment stations is by Research Work Units (RWU's) rather than functional staffs. Authority at the stations descends from the Station Director to the Assistant Director for Research to the Project Leaders and Program Managers. The organization of staff scientists according to RWU's allows scientists to participate on studies within their specific areas of expertise as well as on teams where scientists from diverse areas work to solve complex management problems.

RWU's are plans which define the problems to be addressed by a specific research team and describe how that team will proceed with the study. RWU's may be prepared for studies lasting up to 5 years. The plans are evaluated after the third year of funding to determine if changes in direction are needed and if the study is progressing satisfactorily. During FY 1979, 51 RWU's were funded through FI&DR programs.

Accelerated Pest Programs (formerly the USDA Combined Forest Pest Research and Development Program)

In 1974, the USDA began the Combined Forest Pest Research and Development Program (CFPRDP) to develop methodologies for decreasing forest losses from the Douglas-fir tussock moth, the gypsy moth, and the southern pine beetle. The program called for accelerated research to be conducted on the pests for five years, at which time the expanded research efforts would shift to other pests (Ketcham and Shea 1977).

CFPRDP was administered through the Office of the Secretary, with the Assistant Secretary for Conservation, Research and Education taking lead responsibility (see Figure 3-2A). This organizational structure was developed in order to maintain a high level of program visibility and to enhance cooperation among the four USDA agencies (Agricultural Research Service, Animal and Plant Health Inspection Service, Cooperative State Research Service, and Forest Service), States, and universities. Congress approved a $6 million addition to the Forest Service appropriation to fund the program in FY 1975 and continues to provide special funding for current projects.

Forest Service researchers can participate in both the Accelerated Pest Programs and FI&DR/Experiment Station programs. Funding from two systems increases opportunities for scientists to work on problems associated with accelerated program pests. In order to be funded through accelerated programs, Forest Service scientists must apply for funding in the same manner as university and other non-Forest Service scientists. This dual system of funding encourages competition among the staff scientists and, to a certain extent, the overall research program.

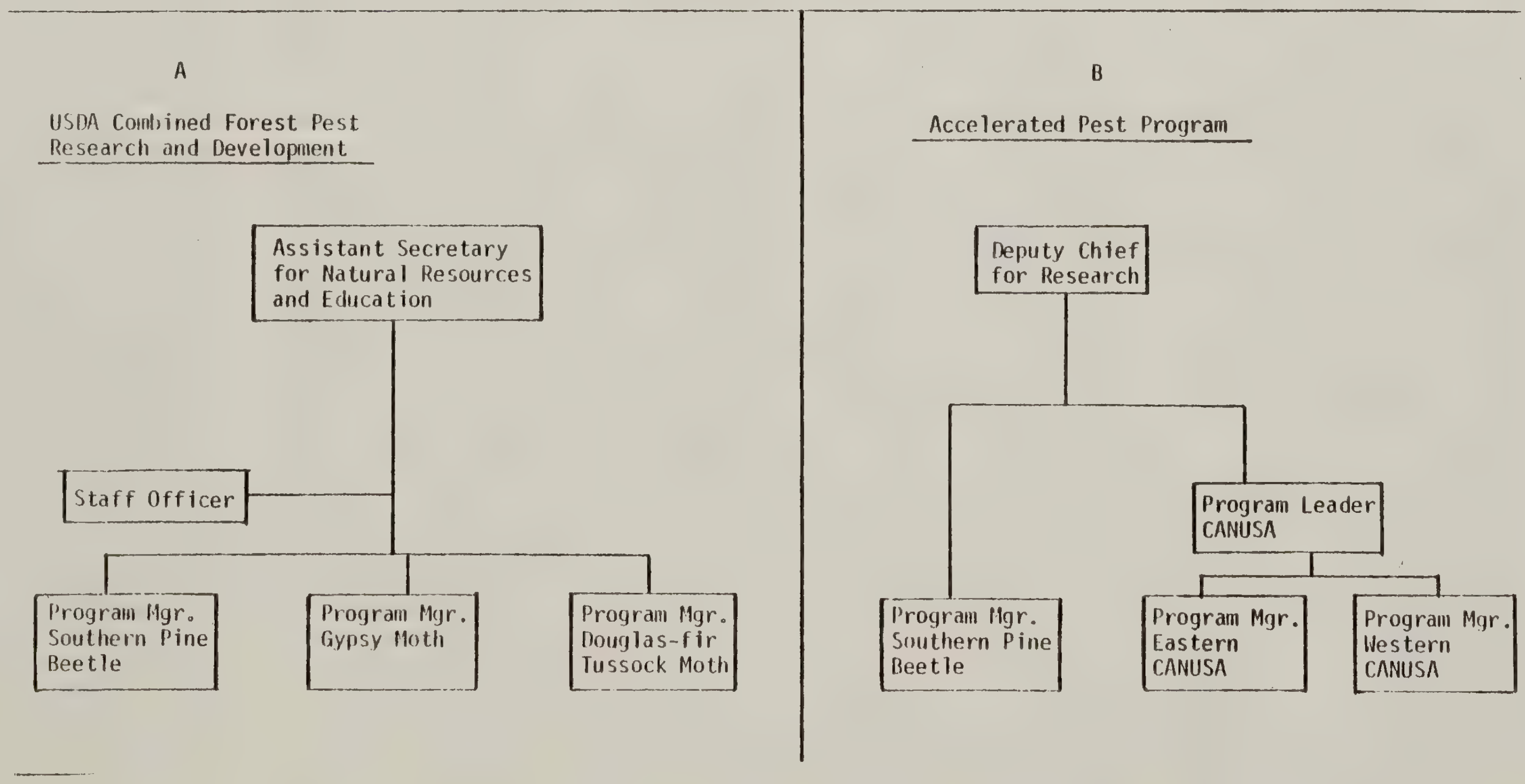
As the Douglas-fir tussock moth and gypsy moth programs were ending in FY 1978, administration of CFPRDP's shifted from the Assistant Secretary's Office to the Forest Service Deputy Chief for Research. In order to maintain the programs as they had developed, they were structured to have the program managers report directly to the Deputy Chief rather than through the Experiment Station hierarchy (see Figure 3-2B).

Another change which occurred at the end of FY 1978 was the initiation of the international Canada-USA (CANUSA) spruce budworm research project. There are Eastern and Western CANUSA projects, each with a program manager. A new position for a CANUSA program leader was created to coordinate the Eastern and Western programs. The Eastern and Western projects closely correspond to funding levels of the concluded gypsy moth and Douglas-fir tussock moth programs. In many cases, some of the same scientists are involved.

The expanded Southern pine beetle program is scheduled to end in FY 1980. At that time, a new program will be developed to deal with forest problems caused by the numerous other bark beetles that infest southern forests.

Attacking the pest problems in this manner required a new, specialized approach. The structure of the CFPRDP gave project managers more than visibility; it gave them access to the highest officials in the USDA Office of the Secretary and the agencies. Transferring the programs into the USDA-Forest Service has exposed them to

FIGURE 3-2. Organization of accelerated insect research programs. Source A: Ketcham and Shea 1977. Source B: Barras, personal communication 1979.



some of the drawbacks of institutionalization even though they retain a unique position in the Research Deputy Area.

Delegation of Authority

Because of the size of the USDA-Forest Service, both geographically and organizationally, the agency decentralizes authority. The Chief, although ultimately responsible for all agency programs and administration, delegates most of the operational responsibilities for land and resource management to the Regional Foresters. It is the prerogative of the Regional Forester to transfer some of these responsibilities to the Forest Supervisors and, in many cases, District Rangers. Pest management responsibilities are delegated to the Deputy Chief of S&PF and then to the Area Directors (Regions 8 and 9) and Regional Foresters in the other Regions. Actual land management authority is vested in the line officers in the NFS Deputy Area.

FI&DM staffs provide technical expertise, conduct detection and evaluation surveys, and suppress pest outbreaks. They serve as advisors to Regional Foresters, Forest Supervisors, and District Rangers on NFS lands, other public agencies, States, and private landowners. FI&DM personnel are often delegated pesticide approval responsibilities by the line officers because of their expertise. Table 3-1 shows that authority for FI&DM programs is placed in the Area Director's and Regional Forester's offices.

3.2 Forest Service Functions Within the Department of Agriculture

As an agency within the Department of Agriculture, the USDA-Forest Service participates in a wide variety of formal and ad hoc committees, task forces, and working groups. One or two members of the Washington Office staff usually represent the Forest Service on these intra-USDA committees and the departmental working groups which coordinate activities with other agencies (see Section 3.3). Several work groups exist to coordinate pest management and toxic substances.

The USDA-Environmental Quality Committee is made up of administrators of USDA agencies, including the Chief of the Forest Service. The Assistant Secretary for Natural Resources and Environment serves as Chairman, and the Director of the Office of Environmental Quality is the Executive Secretary of the Committee. There are five subcommittees and work groups which are germane to insect and disease management.

The work groups are established to bring together expertise on various environmental issues and to enhance environmental coordination in the department. Table 3-2 shows the five intra-USDA environmental issue groups and committees pertinent to pest

TABLE 3-1. Summary of delegation of authority for insect and disease control.

	Sec'y USDA	Chief	Reg. For.	Area Dir.	For. Sup.	Dis. Rgr.
All insect/disease management	X					
All forest insect/disease management		X				
Jurisdictional insect/disease management			X	X	X	X
Approve cooperative agreements			X	X		
Approve all proposals over $10,000		X[1]	X	X		
Approve all proposals $10,000 or less			X	X	X	
Approve use of pesticides in designated wilderness areas		X				
Approve non-housekeeping uses of pesticides			X	X	X	
Approve housekeeping uses of pesticides					X	X

[1]with the exception of dwarf mistletoe programs.

TABLE 3-2. Interdepartmental Groups. Sources:
(1) Office of Environmental Quality, Memorandum, Nov. 20, 1978
(2) Office of Environmental Quality, Memorandum, Sept. 17, 1979

GROUP	FOREST SERVICE REPRESENTATIVE
A. Environmental Issue Committees[1]	
1. Environmental Quality Committee (EQC)	Chief
2. Pest Management Subcommittee of the EQC	Chief
3. Steering Committee for the National Agricultural Pesticide Impact Assessment Program (NAPIAP)	Assoc. Dep. Chief, S&PF
4. Work Group on Pest Management	Director FI&DM Alternate: Dir. FI&DR
5. Toxic Substances Control Act Work Group	Asst. Director FI&DM for Pesticides
B. USDA IPM-Evaluation Task Force[2]	Director FI&DM FI&DR staff

management and the position of the USDA-Forest Service representative on each. Forest Service participants on the pest related work groups come primarily from State and Private Forestry (FI&DM) with FI&DR representation on two groups. In addition to the formal groups mentioned above, the Forest Service has representatives from FI&DM and FI&DR on the USDA ad hoc task force to evaluate IPM in order to respond to President Carter's memorandum.

3.3 USDA-Forest Service Interdepartmental Activities

In 1961, the USDA-Forest Service assumed comprehensive, Federal government-wide responsibility for forest insect and disease control, management, and research. Since then, the agency has entered into a variety of joint arrangements -- both formal and informal -- aimed at coordinating their control activities with other Federal agencies and departments. The USDA-Forest Service has also worked with regulatory agencies and Federal departments through broad bilateral memoranda of understanding secured through the USDA. To a lesser extent, the agency has participated in some Federal intergovernmental working groups, but always under the aegis of the USDA. Supplementing these more formalized mechanisms are numerous personal and relatively unstructured lines of communication which have evolved linking the USDA-Forest Service to non-USDA governmental agencies with insect and disease control responsibilities. Among the topics discussed in these consultative forums are issues relating to policy, budget, technical assistance, research and evaluation.

This section focuses on agency participation in two types of formal interagency coordinating arrangements, both of which were established within the last 10 years through joint USDA memoranda of understanding. The first mechanism is the USDA/Environmental Protection Agency Rebuttable Presumption Against Registration (RPAR) process whereby the USDA-Forest Service works through the USDA-Office of Environmental Quality with the EPA to develop pesticide benefit/risk assessments. The second mechanism is a joint memorandum between the USDA-Forest Service and the Department of the Interior (USDI) which establishes FI&DM cooperation for forest insect and disease problems on lands managed by USDI agencies, i.e., the National Park Service (NPS), the Bureau of Land Management (BLM), the Fish and Wildlife Service (FWS) and the Bureau of Indian Affairs (BIA).

Rebuttable Presumption Against Registration (RPAR)

EPA assumed the regulatory responsibility for chemical pesticide registration in 1970. A subsequent administrative interpretation of existing criteria necessary for registration determined that a more effective mechanism would be needed to evaluate attainment of

the criteria. EPA and USDA established the RPAR process in 1975 to provide a structure whereby both agencies gather and assess information on the comparative benefits and risks for continued chemical registration and use. The RPAR process was formally initiated by a joint USDA/EPA memorandum of understanding signed initially in November/December 1976, and later revised in October 1977 and again in January 1979.

RPAR is the regulatory mechanism established by joint memoranda of understanding between EPA and USDA to gather information on the risks, benefits, and exposure levels of pesticides. The process is used when certain risk factors have been exceeded and cancellation of the chemical(s) may be warranted. The USDA-Forest Service participates in the RPAR process through the USDA National Agricultural Pesticide Impact Assessment Program (NAPIAP), which is made up of a Steering Committee, a Technical Advisory Group (TAG), and individual pesticide assessment teams (see Figure 3-3). To date, eleven RPAR assessment reports, i.e., amitraz, benomyl, chlorobenzilate, DBCP, diallate, endrin, Kepone, Pronamide, 1080/strychnine, Treflan, and 2,4,5-T, have been completed. RPAR process has been completed on six of these-amitraz, benomyl, Kepone, chlorobenzilate, Treflan, and endrin. Table 3-3 shows that Forest Service participation on insecticide and fungicide RPAR assessment is closely connected to forestry and wood-related uses of the pesticides.

Normally, the RPAR process begins with the EPA's determination that an assessment is needed. The USDA's TAG then recommends assessment team members primarily from USDA agencies and EPA, with additional members coming from states, universities, or other Federal agencies. EPA has the responsibility for determining and assessing risks, whereas USDA assesses benefits and exposure. The teams collect data on biological and economic benefits, chronic and acute exposures which might relate to the registered uses, as well as identify data gaps that might be reasonably filled. Teams then formally report their findings to EPA.

The next step is for EPA to analyze the risks and benefits as stated in the assessment team reports. Based on this analysis, the Administrator of EPA determines whether to approve the pesticide for continued use or to cancel some or all of the chemical's uses. If the Administrator exercises the cancellation option, registrants (usually industry) still have the opportunity to request a judicial review of the decision.

The level of USDA-Forest Service participation on joint RPAR assessment teams with colleagues from both EPA and other USDA agencies depends upon: a) the nature of the pesticide under study and its relation to forest weed, insect, or disease control; and b) the discretion of a USDA-TAG. Under NAPIAP, TAG plays a

FIGURE 3-3. USDA NAPIAP/RPAR Organization. Source: Office of Environmental Quality, Charles E. Smith, Internal memorandum, June 20, 1978.

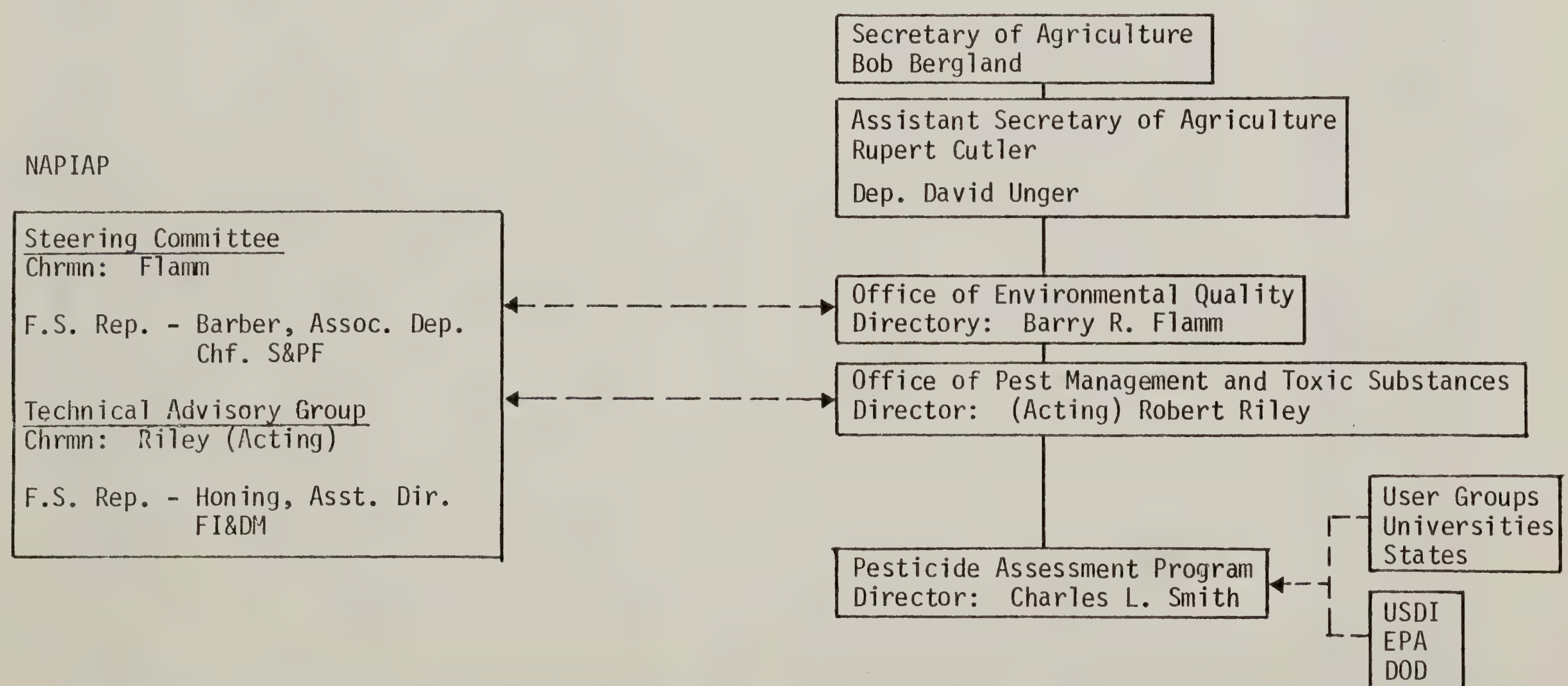


TABLE 3-3. USDA-Forest Service participation in joint USDA/EPA RPAR assessments for insect and disease control pesticides (Sources: EPA, 1979 and Graham, personal communication, 1979).

Chemical	Date of RPAR issuance	No. of USDA-FS participants[1]	Other Comments
A. Benomyl/Thyophenate methyl	12-6-77/12-7-77	1	combined RPAR
B. Benzene hexachloride/Lindane	10-19-77/2-17-77	2	combined RPAR
C. Coal tar Creosote Various inorganic arsenicals Pentachlorphenyl & derivatives	10-18-78	6[2]	wood preservatives
D. Dimethoate	9-2-77	1	
E. Ethylene dibromide	12-14-77	1	
F. Toxaphene	5-25-77	1	

[1]Joint USDA/EPA RPAR assessment teams vary in size between 10 and 15 people. The majority of the participants are from USDA.

[2]USDA-Forest Service representatives assumed assessment team chairmanship.

primary role in assigning RPAR team memberships to relevant USDA agencies such as the USDA-Forest Service. Such recommendations are regularly reviewed but seldom altered by the USDA Steering Committee, which monitors pesticide registration from a departmental policy-making perspective. USDA-Forest Service personnel, from FI&DM, are frequently members of the assessment teams.

Based on the relatively brief existence of RPAR (4 years) and the differences of each assessment, it is difficult to determine the overall effectiveness of the USDA/EPA cooperative relations. Several factors contribute to this situation. To begin with, the RPAR process has turned out to be a far less intensive and short-term decision-making mechanism for pesticide assessment than was initially envisioned. Once in operation, the procedure has proven to be lengthly and at times difficult to complete according to joint agency work schedules. It also has been encumbered by certain interagency biases and prejudices. These problems are aggravated in part by the division of RPAR labor: USDA evaluates the benefits and EPA assesses the risks.

RPAR has been evolving rapidly since its establishment. Accordingly, joint agency guidelines directing the assessment teams' methodologies have also been dynamic and relatively short-lived. Because of the ever-changing requirements of specific pesticide teams, strategies, and assessment substance, one USDA official concluded that of the eleven RPAR assessment reports completed to date, none could be characterized as truly typical. Each pesticide issue arising to date has proven to be unique in substance as well as the style in which it was processed.

In many ways, the RPAR mechanism has benefited from this flexibility. However, the flexibility has also resulted in cooperative problems between USDA and EPA. Members of the two agencies have experienced some difficulty arriving at jointly acceptable formats for economic cost/benefit criteria. Without common criteria for assessment, comparison of the benefits and risks can be greatly hindered. On some occasions, failure to resolve problems like this has disrupted RPAR assessments.

USDA/USDI Insect and Disease Coordination

The general terms of coordination between the USDA and the USDI on forest insect and disease management matters are contained in a joint memorandum of understanding signed in August, 1978 (USDA/USDI 1978). This document supercedes an earlier arrangement concerning forest insect and disease surveys and control, which was approved by the respective departmental secretaries in December 1961 (USDA/USDI 1961). The more recent memorandum stems in part from the intergovernmental consultation mandates specified in Section 5 of the Cooperative Forestry Assistance Act of 1978 (16

U.S.C. 2101). This section authorizes the Secretary of Agriculture to protect from insects and diseases, trees and forests, wood products, stored wood, and wood in use on National Forest System lands and to promote cooperation with other Federal land managing agencies, the States, and private owners on other forest lands. The USDA-Forest Service has responsibility for carrying out the provisions of this Act.

In addition to these broad topics, the memorandum specifies seven responsibilities ultimately falling to the USDA-Forest Service for execution. In summary these are to:

(1) Provide overall leadership and finance coordination for insect and disease control activities on all forest lands.

(2) Provide and finance such technical assistance as may be requested by agencies of the USDI for pest control projects and programs on forest lands administered by USDI.

(3) Perform and finance detection surveys and the entomological or pathological evaluation of insect and disease outbreaks on forest lands administered by USDI.

(4) Transfer USDA funds to the USDI for insect and disease control work as may be needed.

(5) Keep affected agencies of the USDI informed of insect and disease conditions on forest lands or other ownerships that may affect lands administered by the USDI.

(6) Suppress insect and disease outbreaks on the National Forests and cooperate with affected agencies to suppress insect and disease outbreaks on other public land and private lands which threaten forests on lands administered by USDI.

(7) Train key USDI employees in techniques for the prevention, detection, and suppression of destructive forest insects and diseases and to recognize potential hazards caused by forest insects and diseases.

Complementary duties of the USDI are also detailed.

The BLM and the NPS are the two USDI agencies most frequently involved in forest pest management with USDA-Forest Service although the FWS and BIA also work with FI&DM staffs. In the case of the BLM, the majority of interaction occurs in the field between district officers and USDA-Forest Service FI&DM and FI&DR staffs. In addition to forest insect and disease management assistance, BLM also greatly benefits from research activities of the Forest Service (Petersen 1979, personal communication). A number of special cooperative programs have been established ranging from joint clearance efforts and commercial logging sales, e.g., mountain pine beetle salvage, to research and development affiliations, e.g., a Western Oregon program to study the white pine blister rust problem.

A BLM Forestry Division spokesman (Peterson 1979, personal communication) identified only one area where coordination with USDA-Forest Service could be upgraded: alternative mechanisms for improving the BLM's input into insect and disease research. Although traditionally a production-oriented unit, BLM is currently broadening its pest management perspective; better access to research represents a top priority.

Funding for BLM forest insect and disease management projects is a "pass through" from USDA-Forest Service FI&DM budgets. BLM supplies FI&DM with anticipated budgets and the BLM requests are included in FI&DM's budget proposals. BLM criteria for determining their fiscal needs are the same as those of the Forest Service. When FI&DM funds are allocated, BLM's portion is sent directly to the agency. When additional funds are needed, usually for major suppression activities, FI&DM receives a BLM evaluation of the pest problem and the proposed project. FI&DM routinely supplies both initial (fiscal year) and additional (emergency suppression) allocation funds. BLM officials are content with the fiscal cooperative arrangements.

The NPS coordinates with USDA-Forest Service largely in two situations. The first involves consultations and environmental impact evaluations initiated by USDA-Forest Service when one of its insect and disease control projects occurs on lands close to National Park areas. While NPS normally welcomes such evaluations, they are not obliged to implement USDA-Forest Service recommendations with regard to treatment. This seldom causes interagency friction to any significant degree. However, it frequently does bring to light the different philosophies toward insect and disease control held by the NPS and USDA-Forest Service. NPS philosophy often considers pests as part of the natural system which the parks are created to protect, therefore, suppression of the pests may not be the objective of NPS.

The second, albeit far less frequent, situation for NPS/USDA-Forest Service coordination arises when--through its own monitoring--NPS identifies an insect and disease control problem and requests program funds. Although normally quite small in scale, such fiscal needs must be transmitted to USDA-Forest Service for review and processing. Once approved, programs are accomplished entirely by the NPS without USDA-Forest Service staff or equipment. In these circumstances, the USDA-Forest Service has little influence in how the projects are planned, implemented, or evaluated after completion. NPS suppression projects funded through this agreement are not examined with the same economic and environmental criteria as are in-house projects. Post-treatment evaluations are not required. The arrangements present a pattern of USDA-Forest Service funds being supplied on request from USDI without the USDA-Forest Service requirements for projects being applied.

Federal Intergovernmental Working Group on Pest Management (FIWGPM)

The USDA-Forest Service has in the past participated in the FIWGPM an interagency committee for coordinating insect and disease control matters. This entity, with a history of coordination going back into the 1940's, is presently dormant, having lost funding support from both the Office of Management and Budget and EPA in 1976 just after EPA was designated the "lead" agency. The USDA-Forest Service contributed half (one representative) of the USDA's membership on the group's 8-person policy recommendation making team, and also regularly supplied technical staff to its insect and disease arrangements panels while the group was operational.

SUMMARY

Forest Insect and Disease Management staffs are part of the State and Private Forest Deputy Areas, the organization of which varies geographically. In the West (R-1,2,3,4,5,6, and 10), S&PF is organized in the Regional Forester's office, whereas in the East (roughly R-8 and 9), S&PF is administered through Area Directors who are not direct subordinates to the Regional Forester. In both cases, FI&DM and overall S&PF responsibilities are the same--to protect and preserve the Nation's forest resources from forest insect and disease hazards. As part of S&PF, FI&DM units work closely with state foresters, private landowners, and all Federal agencies to solve problems involving forest insects and diseases.

Forest insect and disease research activities are divided into two organizational structures: the Accelerated Pest Program and the FI&DR staff group. Accelerated programs are administered directly through the Deputy Chief for Research, and so are not part of the usual Experiment Station hierarchy.

Representatives of the USDA-Forest Service from FI&DM and FI&DR serve on several intra-USDA and inter-governmental work groups and committees, often through the USDA-Office of Environmental Quality. These groups deal with a wide range of environmental protection areas including pest and pesticide management. FI&DM and FI&DR staffs also work with other Federal government land managing agencies to solve forest pest problems. The Forest Service responsibility to provide assistance to these agencies and the private sector includes funding and conducting research to improve pest management technologies.

4.0 THE ROLE OF INSECTS AND DISEASES IN FOREST MANAGEMENT

Forest ecosystems consist of a complex network of physical, biological, and social interactions. Physical characteristics important to the understanding of a forest ecosystem include soil, topography, climate, and geology; social phenomena of importance are objectives of management, values attached to the resource, economic rate of return desired, legal/institutional constraints, and externalities associated with management. Important biological factors are the tree-shrub-herbaceous vegetation complexes, wildlife, micro-organisms, insects, and diseases. The impact of any one of these physical, biological, or social factors cannot be legitimately analyzed in isolation from other factors impinging on a forest ecosystem; change in any one of these many factors can have repercussions throughout the ecosystem.

4.1 The Importance of Insects and Diseases in Forest Ecosystems

The impact of insects and diseases on forest ecosystems can vary from beneficial to innocuous to damaging. Insects and diseases play a vital role in the forest biodegradation process and are important links in a myriad of food chains. Their influences on the stand variables of age structure, species composition, and density are natural forces that may greatly affect forest successional patterns by accelerating or slowing down the successional processes. While forest insects and diseases can adversely affect management objectives, or outputs, which man has planned for the forest; man's activities in meeting management objectives also can influence forest ecology, and at times cause changes which facilitate insect or disease outbreaks.

Direct losses of forest resources due to insects and diseases include mortality, growth loss, stand deformation, and wood biodegradation. Annual mortality losses from natural causes, e.g., fire, insects, diseases, and weather for timber resources in the United States was approximately 4 billion cubic feet of growing stock in 1977. Mortality of sawtimber amounted to approximately 12 billion board feet. Timber mortality on National Forests amounted to 1 billion cubic feet of growing stock, including 4.4 billion board feet of sawtimber. The primary cause of death was considered to be insect infestation and drought (USDA-Forest Service, 1979g). The annual growth loss of timber from disease in Oregon and Washington alone has been estimated to be 403 billion board feet (Miller and Committee 1975; after Childs and Shea 1967)

Of the countless species of insects and diseases present in forest environments, few (Appendix Tables 1-3) are presently considered detrimental to management objectives. However, judicious forest management requires recognition of the presence and potential impact of all pest species. Management strategies must incorporate provisions for combatting potential pest problems.

Management objectives determine whether an insect or disease is a positive or negative force in a particular situation. For example, an old growth forest is extremely vulnerable to attack by both insects and diseases. If the primary concern of management is to reap the largest economic return possible from that stand, pest-induced losses cannot be tolerated. However, if the principle management concern is the maintenance of a contiguous forest canopy and the gradual replacement of the mature trees with a tolerant timber species, an endemic insect or disease population may prove fruitful for the accomplishment of that objective.

The definition of a "pest" in terms of management objectives is probably more crucial to forestry than to other production-oriented biological sciences. With the passage of the Multiple Use Sustained Yield Act in 1960 which set the legal basis for multiple objectives in forest management in conjunction with the differing objectives for Federal lands, the multiple objectives based on forms of forest ownership in the United States vastly increased the complexity of determining when an insect or disease is innocuous, beneficial or detrimental. The USDA-Forest Service, charged with the authority to protect trees and forests on all forest lands from insects and diseases, must determine when an insect population is an asset or a liability. Adjacent properties with differing objectives can make the decision by the Forest Service on an insect or disease pest status extremely difficult.

4.2 The Impacts of Insects and Diseases on Various Forest Land Uses

The impact of insects and diseases varies in relation to the particular use of the forest land involved. A decrease in commercial forest production due to insects or disease may have a significant impact because of the importance of timber production to the wood products and housing markets whereas a similar outbreak in a recreational area might have little or no impact, as long as the pest does not disrupt the recreation experience.

Extraction of forest products in the United States constitutes 5 to 6 percent of the gross natural product. Impacts on this component of the U.S. economy may occur because of growth and quality losses resulting from endemic and epidemic levels of insects and diseases. Because of the link between timber harvesting and the national economy, most insect/disease control or

prevention efforts have been for the protection of the timber management objective of forest land use.

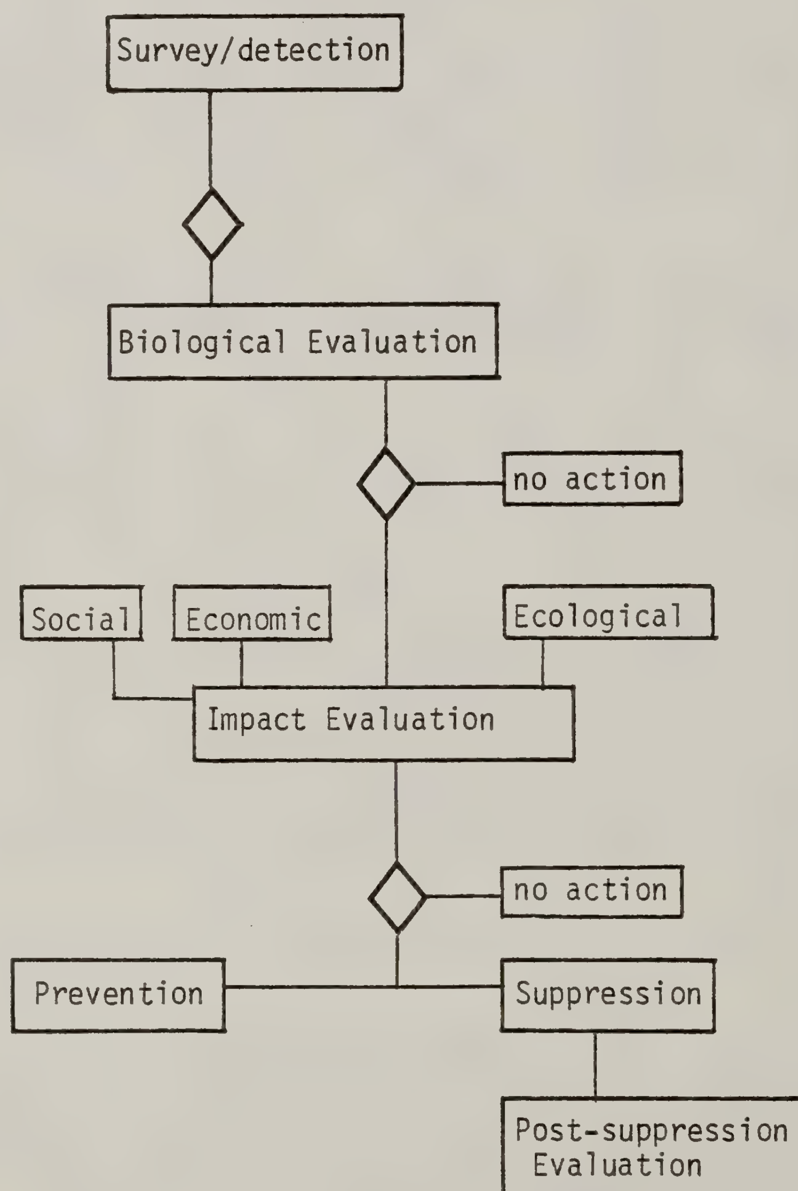
Forage resources associated with forest lands have rarely been studied in the context of insect and disease population dynamics but efforts to increase the grasses and herbs associated with particular forest types can be compatible with both timber management objectives and the reduction of an insect or disease population. A classic case is the burning of southern longleaf pine plantations to reduce the incidence of the brownspot needle blight. The burning is favorable to the pine and can substantially increase the forage value of the area.

In outdoor recreation the status of insects and diseases as pests is highly variable. Recreational demand has increased rapidly in the last two decades requiring management objectives on particular forested areas change markedly. This tremendous growth in recreation demand, coupled with rapidly changing preferences, policies, and laws makes determining how insects and diseases fit into outdoor recreation management very difficult. Although policies of "letting nature take her course" in wilderness areas seem compatible with the objectives established for such areas, epidemic outbreaks of pests do not recognize the arbitraily established boundaries imposed by man. The degree of damage which can be tolerated by wilderness enthusiasts is yet to be defined. In intensively managed recreational areas, unsightly pest damage can significantly decrease the aesthetic values of a resource. The mountain pine beetle epidemic on the Front Range of Colorado is a good example of the impact an insect can have on the desirability of a recreational resource. Further, insidious decay organisms may predispose large trees to structural failure and create extremely hazardous conditions in campgrounds.

The direct impact of insects and diseases on soils and watersheds is relatively insignificant. Even a massive epidemic which leads to extensive mortality is unlikely to destroy soil stabilizing factors in forest areas. The most significant impact of a pest outbreak on watersheds may be more a result of man's response to the outbreak than the direct biological repercussions themselves. Management techniques incorporating inappropriate pesticide applications could prove far more damaging to a watershed than the pest outbreak itself. Also, if poorly executed, road construction activities associated with the salvaging of dead and dying trees could have a drastic impact on water quality, aquatic organisms, and wildlife.

Wildlife resources, like soils and watersheds, may be altered more by man's response to insect and disease outbreaks than to the outbreaks per se. Aerial applications of pesticides can be hazardous to aquatic organisms and can alter the habitat in which

FIGURE 4-1. Pest Management Processes



they live. Salvage operations can markedly change upland habitat, thus altering the wildlife composition in an area. Changes in upland game habitat could also result from the pest damage itself, and in some cases, this damage alone can be drastic enough to change wildlife species composition and numbers.

4.3 Pest Management Principles

Although there is no single standard insect survey, most include both detection and evaluation elements. Periodic surveys approximate the number and distribution of particular insect or disease pests. These elements serve, in turn, as the basis for formulating prevention and control strategies. Figure 4-1 is a schematic of the process by which treatment strategies for insect pests are derived. Each step in the diagram is explained in the following chapters of this report (Survey and Evaluation, Chapter 5; and Prevention and Suppression, Chapter 6) and a more comprehensive model of integrated pest management and its components is discussed in Chapter 7.

Control of pathological stress is normally limited to intensively managed or special use forests. The vast majority of extensively managed commercial forest lands in this country receive minimal direct control and some minor silvicultural control of disease pests. The silvicultural methods employed include proper species and site selection, thinning, pruning, fertilizing, and rotation length control.

Pesticides (fungicides, nematocides, and herbicides--all of which may control tree disease under some circumstances) have been confined to specialty forests and highly valued individual trees. On the several thousand acres of specialty forests such as nurseries, seed orchards, windbreaks, and Christmas tree plantations, the primary pathological stress controls are both cultural and pesticidal and are frequently intensive (Miller and Committee, 1975).

SUMMARY

Forest insects and diseases are vital components of forest ecosystems, serving as links in a complex food chain and accelerating biodegradation processes. Nevertheless, insects and diseases can also adversely affect forest management objectives by killing trees, reducing growth, and causing other types of injury. Dead, dying and defoliated trees may detract from aesthetic experiences of recreationists and/or reduce cover availability for wildlife species. At present, the most significant impact of forest insects and diseases is on commercial timber.

5.0 SURVEY AND EVALUATION

Successful management of forest pests requires forest managers to know what insects and diseases are present and/or threatening. The manager must be able to predict the effect of the presence of a pest or pest complex on his objectives for managing the land and its resources. Detection surveys, biological evaluations, and impact evaluations provide forest managers with this information. Detection surveys on Federal, State, and private forest lands comprise a major part of the USDA-Forest Service FI&DM activities.

This chapter describes and analyzes the methods that the USDA-Forest Service uses to conduct surveys and evaluations. Regional comparisons of acres surveyed show that major variations in accomplishments correlate closely with major pest problems.

5.1 Survey and Detection Activities

FI&DM has sole responsibility for insect and disease surveys on National Forest and other Federal lands, and frequently cooperates with State and private agencies to survey non-Federal lands. Table 5-1 shows the approximate acreages surveyed in each Region/Area during 1977-79. Nearly twice as much S&D has been conducted on State and private lands as on National Forests in recent years. The Northeastern Area (NA) and Southeastern Area (SA) show the most activity as a result of intensive monitoring efforts in conjunction with spruce budworm and southern pine beetle infestations.

Survey and detection (S&D) activities on National Forests can be traced back to the 1920s, when District Rangers conducted bark beetle and defoliator surveys from vantage points on mountain tops and ridges (Johnson and Denton 1975). Ground surveys predominated until the early 1950's, when more efficient aerial surveys began to replace or supplement them. Since the 1950's refinements in aerial photography have enabled more precise surveys to be conducted over larger areas. The most advanced schemes utilize images from LANDSAT data. However, for some insects and diseases, ground surveys remain the best technique to date.

Routine FI&DM surveys are conducted through aerial reconnaissance and sketch mapping. From the air, dead and defoliated trees can be spotted and mapped for further evaluation. Aerial reconnaissance allows spotters to track the spread of insects and diseases. Annual S&D programs utilizing aerial reconnaissance techniques (sketch mapping) are used throughout the country.

TABLE 5-1. Total forest lands (in acres) subjected to aerial detection surveys by or in cooperation with the USDA-Forest Service, 1977-1979.[1]

	YEAR	REGION/AREA 1	2	3	4	5	6	SA[2]	NA	10	TOTAL
NATIONAL FOREST LANDS	1977	24,482,157	7,809,000	20,618,383	17,545,900	14,295,749	26,993,022	12,906,215	22,003,907	19,191,400	165,845,733
	1978	16,895,200	6,303,360	10,652,313	17,559,800	22,758,000	23,832,465	13,720,025	2,019,280	9,995,400	123,735,843
	1979	19,504,218	4,631,080	10,652,292	7,103,451	1,817,228	23,832,447	---	1,770,500	9,185,840	78,497,056
	TOTAL	60,881,575	18,743,440	41,922,988	42,209,151	38,870,977	74,657,934	26,626,240	25,793,687	38,372,640	368,078,632
STATE AND PRIVATE LANDS	1977	25,053,753	5,819,962	3,179,530	50	11,008,000	25,403,140	181,657,157	73,973,029	1,400,000	340,094,621
	1978	2,751,791	4,324,599	1,419,841	0	0	25,301,000	88,586,721	151,896,400	1,715,200	275,995,552
	1979	7,090,380	1,669,070	1,420,725	0	7,734,000	23,235,700	---	148,846,158	2,155,650	192,151,683
	TOTAL	34,895,924	11,813,631	6,020,096	50	18,742,000	73,939,840	270,243,878	374,715,587	5,270,850	795,641,856
OTHER FEDERAL LANDS	1977	5,237,065	2,623,000	5,296,177	374,000	0	6,131,536	2,463,052	11,000	23,700.000	45,835,830
	1978	3,209,000	2,483,060	2,602,160	376,300	0	6,037,062	324,535	2,200	11,014,400	25,048,717
	1979	3,329,750	549,140	2,541,148	88,000	7,695,678	5,883,712	---	1,000	12,476,500	32,564,928
	TOTAL	11,775,815	4,655,200	10,439,485	838,300	7,695,678	18,052,310	2,787,587	14,200	47,190,900	103,449,475
GRAND TOTAL		107,553,314	35,212,271	58,382,569	43,047,501	65,308,655	166,650,084	299,657,705	400,523,474	90,834,390	1267,169,963

[1] Source: USDA-Forest Service, FI&DM, Rossyln, Virginia.

[2] FY 1979 data not available for Southeast Area.

Aerial sketch mapping is the preferred survey method in all Regions except 5 where aerial photography is utilized in the Pest Damage Inventory (PDI). Aerial sketch mapping is useful in delineating defoliator infestations but is much less effective in dealing with the widely scattered mortality characteristic of the pest complexes in R-5 (see Section 5.2).

Ground surveys are currently conducted in conjunction with routine stand entries. This can be an efficient method of S&D if personnel on the ground are adequately trained in the identification of pest problems. However, most of the time when stands are inventoried, entomologists and pathologists are not part of the survey crews. In some Regions, FI&DM holds insect and disease training sessions for timber crews to assure quality survey data are collected. However, in Region 8, FI&DM is scheduled to participate for the first time in regional silvicultural workshops to be held in the spring of 1980.

Ground surveys are employed most extensively for detection of diseases like dwarf misletoe and fusiform rust. Rather than causing mortality or defoliation, these diseases cause more subtle effects like stem deformation and growth loss that are not readily apparent from the air.

Special detection projects are conducted by FI&DM whenever routine surveys indicate the need for them. The Forest Service used color infrared photography to identify root disease centers distributed over a wide range of stand and habitat types in northern Idaho (Williams and Leaphart 1978). The infrared film was able to detect mortality in areas that would have been difficult to groundcheck and illuminated patterns that were not visible to eyesight or normal film.

Methods for identifying and detecting root diseases are still in a fairly primitive stage of development and need to be refined. Survey data describing the distribution of root pathogens within forest stands are generally lacking and need to be obtained before these diseases can be effectively managed (Parmeter 1980, personal communication). Plantation diseases, e.g., fusiform rust, pitch and scleroderris cankers, have been the object of numerous intensive ground surveys in the Northeastern (NA) and Southeastern (SA) Areas during the past few years, as the importance of these diseases has become recognized.

The shortcomings of reconnaissance surveys in the detection of insect outbreaks before significant damage has occurred has prompted FI&DR scientists at the Pacific Northwest Experiment Station and researchers working through the Accelerated Pest Programs for Douglas-fir tussock moth, gypsy moth, and southern pine beetle to concentrate on methods to detect incipient out-

breaks. Understanding population dynamics at pre-outbreak levels is a key to determining the probability of future outbreaks. One of the most promising new methods for detecting incipient outbreaks of destructive insects is the use of traps baited with chemical sex attractants. The Douglas-fir tussock moth predictive trapping system is now in use on National Forest lands in Regions 1, 5, and 6; on State lands in several western states; and on private lands of Boise Cascade Corporation and Weyerhauser Company (USDA-Forest Service 1979d). The attractant trapping system reduced the need for less efficient egg and larval sampling procedures used in the past. Operational detection systems utilizing chemical attractants for introduced insects also exist for gypsy moth, European pine shoot moth, and the smaller European elm bark beetle.

5.2 Biological Evaluation

There are two categories of biological evaluations (BE's): pre-suppression and post-suppression. Both types employ similar methods and are conducted to measure and predict pest populations. Data collected in BE's are used to determine whether or not control efforts are warranted and to determine the effectiveness of a particular treatment. In general, biological evaluations are only conducted when pest problems exist or are threatening. FI&DM conducts BE's in response to requests from National Forests, other Federal lands, and routinely in areas where particular pests are known to pose a significant threat. Pre-suppression BE's are required in all environmental impact statements for insect and disease suppression operations and, if pesticides are used, post-suppression evaluations must also be reported.

Accomplishments of presuppression BE's for 1977 and 1978 are given in Table 5-2. In general, evaluation data record only the acres actually evaluated. However, in the Southeastern Area (SA), evaluation accomplishments are considerably higher (by an order of magnitude in 1977 and 1978) because the evaluated area reported is determined by calculating the "area protected" from the on-the-ground evaluations. The "area protected" as a result of an evaluation is the acreage of similar forest type in the vicinity of the evaluation (Swain 1979, personal communication). Accordingly, SA data cannot be used in comparing National pre-suppression BE trends, and the discussion herein excludes it.

On National Forest lands, pre-suppression BE accomplishments were predominantly in the West where, during 1977 and 1978, western spruce budworm (Regions 1 and 6) and mountain pine beetle (Regions 2 and 4) outbreaks occurred. On State and private lands the Maine spruce budworm outbreak evaluations accounted for 99 percent of all evaluations on State and private forest lands. What evaluations there were for the West were dominated by budworm and

TABLE 5-2. Total forest lands (by acre) subjected to presuppression biological evaluation by or in cooperation with the USDA-Forest Service, 1977-1978.[1,2]

	Year	REGION/AREA 1	2	3	4	5	6	SA[3]	NA	10	TOTAL
NATIONAL FOREST LANDS	1977	3,620	32,202	0	24,649	0	300,000	15,682,430	0	0	360,471
	1978	8,258	113,454	40,992	68,394	0	12,828	10,980,668	0	0	243,926
	TOTAL	11,878	145,656	40,992	93,043	0	312,828	26,663,098	0	0	604,397
STATE & PRIVATE LANDS	1977	0	456,359	0	0	0	840,235	214,829,642	1,081,000	0	237,759
	1978	0	467,968	800	0	0	447,500	94,784,684	5,894,014	0	6,910,282
	TOTAL	0	924,327	800	0	0	1,287,735	309,614,326	6,975,014	0	9,187,876
OTHER FEDERAL LANDS	1977	0	0	0	0	0	5,000	9	0	0	5,000
	1978	0	0	0	0	0	1,027	0	200	0	1,027
	TOTAL	0	0	0	0	0	6,027	9	200	0	6,227
GRAND TOTAL		11,878	1,069,983	41,792	93,043	0	1,606,590	336,277,433	6,975,214	0	9,793,500

[1]Data obtained from the USDA-Forest Service, FI&DM, Rossyln, Virginia.

[2]FY 1979 data not available.

[3]Data reporting system for SA differs from all other Region/Areas and consequently cannot be used for inter-Region/Area comparisons.

mountain pine beetle. Pre-suppression evaluations on other Federal lands were limited.

Post-suppression BE accomplishments in 1977 and 1978 (Table 5-3) were considerably lower than pre-suppression accomplishments in most Regions. Regions 1, 2, and 3 conducted presuppression evaluations but no post-suppression BE's in those years. This situation can be explained by noting that pre-suppression evaluations are conducted to determine if suppression activities are needed or not. However, by definition, post-suppression evaluations are only conducted after a suppression project has been undertaken. Data on the SA post-suppression evaluation accomplishments are more comparable to the Regions and to the NA than are the presuppression figures. Combined SA and NA post-suppression activities on State and private lands account for 79 percent (33 percent SA, 46 percent NA) of the national accomplishments. SA and NA activities during this time emphasized southern pine beetle and spruce budworm epidemics.

Sampling techniques are continually being refined and often help to generate data that are compatible with advanced statistical analyses. Research funded through the Canada/USA Spruce Budworms Program (CANUSA) includes: (1) a project designed to improve larval sampling for spruce budworm at low and moderate population levels, and (2) projects designed to develop pheromone sampling systems for both western and eastern spruce budworms. While the USDA Expanded Douglas-fir Tussock Moth R&D Program has generated specific sampling techniques for this insect, methods for other important defoliators still require additional refinement.

In response, Forest Service researchers are working to develop and improve sampling techniques for defoliators and bark beetles. The Northeast Experiment Station (NE) has researched sampling techniques for the gypsy moth and the European pine sawfly. Through the Accelerated Gypsy Moth Program, new methods of detecting incipient moth population levels have been developed. In the South, research on the southern pine beetle has been underway for many years and four (4) years with the USDA Expanded Southern Pine Beetle R&D Program. Recent advances include evaluation techniques based on beetle flight patterns and dispersion frequency.

Research at the Methods Application Group (MAG) in Davis, California, is currently coordinating a project to refine and standardize egg mass sampling procedures for western spruce budworm. This project is in its third year of evaluating the accuracy of egg mass counts to predict defoliation levels the following year and has made significant progress (Ciesla 1979, personal communication).

TABLE 5-3. Forest lands (in acres) subjected to post-suppression biological evaluation by or in cooperation with the USDA-Forest Service, 1977-1978.[1,2]

	YEAR	REGION/AREA 1	2	3	4	5	6	SA	NA	10	TOTAL
NATIONAL FOREST LANDS	1977	0	0	0	6,000	0	355,973	11,409	0	0	373,382
	1978	0	0	0	0	0	12,000	0	0	0	12,000
	TOTAL	0	0	0	6,000	0	367,973	11,409	0	0	385,382
STATE & PRIVATE LANDS	1977	11,000	0	0	2,000	0	100,221	452,961	54,633	0	620,815
	1978	8,000	408,246	0	0	0	10	982,988	1,981,822	0	3,381,066
	TOTAL	19,000	408,246	0	2,000	0	100,231	1,435,949	2,036,455	0	4,001,881
OTHER FEDERAL LANDS	1977	0	0	0	0	0	480	0	0	0	480
	1978	C	0	0	0	0	0	0	600	0	600
	TOTAL	0	0	0	0	0	480	0	600	0	1,080
	GRAND TOTAL	19,000	408,246	0	8,000	0	468,684	1,447,358	2,037,055	0	4,388,343

[1]Source: USDA-Forest Service, FI&DM, Rossyln, Virginia.

[2]FY 1979 data not available.

Population prediction models are helping to determine changes in pest populations levels with greater accuracy. Population prediction models have been, or are being, developed for major pests such as mountain, western, and southern pine beetle, gypsy moth and spruce budworm. Although the visible development of most of these models has been in conjunction with well-financed accelerated research programs, significant progress in this area would have been impossible without the years of population dynamic studies that supplied much of the necessary background information. A tussock moth population outbreak model has been developed through the Accelerated Program and should be fully operational during the next tussock moth outbreak (although its accuracy has yet to be fully validated). One of its uses will be to predict future moth population and defoliation levels once an infestation has been classified as having reached outbreak status (Colbert 1979).

In general, BEs insect/disease complexes are less refined and are conducted far less often than insect BEs. However, there is mounting evidence that insects (especially bark beetles) and diseases often act in concert to cause mortality that had previously been attributed solely to insects (Parmeter, Wood, 1979, personal communications). Research on pest complexes has been very scant in the past and a recent task force report on forest pest research recommended that such research be assigned a higher priority (USDA-Forest Service, 1976).

Pest complexes are the major emphasis of BEs in Region 5 where widely-scattered mortality is caused primarily by various combinations of bark beetles, root diseases, and dwarf mistletoes. The Region 5 Pest Damage Inventory (PDI) combines survey, biological evaluation, and damage assessment into one, cohesive operation. This system utilizes aerial photography to detect dead trees and ground truths to determine the cause(s) of mortality. Once the different types of mortality are quantified and related to site and stand conditions, silvicultural management strategies may be developed to prevent further mortality from occurring. Estimates of the level of tree mortality and cause(s) of that mortality can also be used by administrators to set research and action priorities (Byler 1979, personal communication).

Biological evaluation procedures for root diseases involve the accurate identification of a pathogen and an estimation of its rate of spread throughout the stand. Only crude and inefficient means are available at present to identify root pathogens and it is often difficult, if not impossible, for field personnel to accomplish this task (Parmeter 1980, personal communication). Disease spread rate estimates are needed in order to predict future impacts of uncontrolled disease centers. Some baseline studies have been accomplished in this area but much more informa-

tion is needed in order to develop epidemiological models that will predict rates of spread under a variety of different site and stand conditions (Ibid).

5.3 Impact Evaluation

When a pest outbreak or epidemic has been detected and evaluated biologically, the information on the extent of the outbreak is used, often in a predictive model, to determine the impact that the insect or disease will have. Estimates of the impact are documented in environmental assessments and environmental impact statements. Impact evaluation consists of two major components---ecological and socioeconomic. At a 1972 Forest Service workshop on insect and disease impacts, the following definitions were used to describe these factors:

> "(1) ecological--the cumulative net effects of insects and diseases on the ecological parameters of forest stands or other land management units containing trees; and
>
> (2) socio-economic--the net effects that alter value judgements and/or decision criteria established by management objectives" (USDA-Forest Service 1972a).

Ecological impact is determined by using biological evaluation data and characterizing the threat in terms of how the forest ecosystem will be affected. In cases of severe infestations, pests can drastically alter the stand composition of the forest and thereby cause significant ecological impacts. Consideration must be given to the impact if the pest is not suppressed and compared to the impact if it is suppressed. The impact of the suppression measures must also be included as a factor in the overall ecological impact evaluation.

Socio-economic impact evaluations use the ecological impact assessments to estimate the costs and benefits of each alternative management strategy (including the no action alternative). In most cases, socio-economic impact is more an economic than social evaluation. They predict actual or potential losses from pests to wood and wood products (based on market values) and estimate the pests' effects on non-commodity forest resource outputs, i.e., recreation, wildlife, and watershed (using estimated dollar values). Establishing values for these non-commondity resources can be difficult and thereby hinder the economic impact evaluation. However, even when these values are determined to reflect social preferences, the socio-economic impact evaluations are more economic than social.

Social impacts include health, education, employment, community stability, general social well-being and many other factors. Health, employment, and community stability are all characteristics which can be affected by a forest pest and the management strategy used to control it. Evaluating these factors is difficult to do precisely. Nevertheless, social factors of a forest pest and the treatment strategies should be included as a component of any socio-economic impact evaluation.

Over the years impact evaluation has evolved from a crude estimate of losses based primarily on conjecture into a more refined science. Recent research on impact evaluation has emphasized multi-stage probability sampling techniques and predictive models to estimate the impact of mortality due to bark beetles (Klein et al., 1979), defoliators (Johnson and Denton, 1975), dwarf mistletoes (Walters, 1979), root diseases (Leaphart and Williams, n.d.), and pest complexes (Freeman 1979, personal communication). By combining insect outbreak characteristics with timber stand prognosis models, the likely effectiveness of different control activities on resource outputs can be estimated (Stage, 1975).

Losses due to defoliating Lepidoptera (mortality, growth loss, and cone and seed loss) are more difficult to quantify than losses due to bark beetle mortality. Consequently, there has been a great deal more impact research undertaken prior to and during the accelerated research programs on defoliators than on bark beetles. This research was pioneered at the Pacific Northwest Experiment Station with Douglas-fir tussock moth and western spruce budworm. Long-term studies attempting to relate levels of defoliation to subsequent growth loss and mortality are still being followed today. Predictive models have also been developed to show the impact that a tussock moth outbreak will have on water production, wildlife habitat, recreation, and fire hazards (Schreuder, 1978; USDA-Forest Service 1979d). These models were developed through the DFTM accelerated research program and there has not been a major DFTM outbreak since they were developed.

The Methods Application Group in Davis, California has been significantly involved in advancing new methodologies for assessing damage due to forest pests. Their activities have included: (1) developing improved techniques for damage assessment using aerial photography; (2) engaging in technology transfer activities to facilitate the operational use of the Douglas-fir tussock moth outbreak model and Stage's stand prognosis model; and (3) developing regionwide data management systems to effectively handle loss assessment data on a national scale (Ciesla 1979, personal communication).

Disease impact evaluation techniques and models are less developed than those for insects. Wicker (1978) remarked that impact data for dwarf mistletoes was very slow to develop because foresters were content to selectively harvest stands of old-growth and describe mistletoe damage in qualitative terms only. Root disease impact evaluation techniques suffer from a lack of good qualitative data to predict rates of spread within stands (Parmeter 1980, personal communication).

However, prognostic models have been developed for dwarf mistletoe. Hawksworth (1979, personal communication) provided curves relating growth loss to infestation severity in pure stands of lodgepole pine. These data are incorporated into a simulated yield model (RMYLD) to predict future growth losses. In Region 3, a similar model (SWYLD) is being used for ponderosa pine stands (Walters and Geils 1977). Similar models are needed for other conifer species such as Douglas-fir, larch, and western hemlock (Dooling 1980, personal communication).

A major problem with all models is that they depend on specific data collection methods that are not always followed in the field. The USDA-Forest Service recently held a meeting in Albuquerque, New Mexico (November 14, 1979) to try and remedy problems of this kind related to stand inventory collection (Ciesla 1979, personal communication). Even though problems may be recognized from entomological, pathological, and silvicultural perspectives, defining what data are needed and assuring that the data are properly collected involves teaching many stand examiners what additional characteristics they are to examine. Stand examiner education is a continuing program but there are many examiners who will need additional training if they are going to collect new types of data.

At a workshop in 1972, the USDA-Forest Service noted the following problems with their impact evaluation efforts.

> "The Forest Service does not have an adequate system for measuring, evaluating, and predicting insect- and disease-caused impacts on the forest resources of the Nation. Basically, we lack a clear understanding of the concept and practical implications of pest impacts in the total space-time frame of the resource management process. The data base from past work and the present data inputs are incomplete. Specifications for the kind and quality of data needed, criteria for interpretation and evaluation, and bases for value judgements have not been established on a sufficiently broad scale. We have some, but not all the knowledge and methodology needed to fill these voids.

> The need for adequate insect and disease impact inputs into Forest Service planning and operations is urgent. Public concern for the rationale and justification of forest pest control decisions and the methods used for control is increasing. The balance of production-, protection-, and utilization-oriented activites is under close scrutiny by individuals and groups within and outside the government. The Forest Service needs an adequate impact data and information base for research, inventory, and action programs now" (USDA-Forest Service, 1972a:1).

Although there have been many advances in impact assessment since 1972, the above statement still holds true.

The accelerated research programs have been instrumental in developing impact evaluation techniques and models for specific insects and diseases, but the impacts resulting from the myriad of other insects and diseases have yet to be evaluated adequately. Impact evaluations must include socio-economic variables, many of which have yet to be quantified satisfactorily.

5.4 Risk-Rating Systems

Risk- or hazard-rating systems are used to predict the probability of damage to individual trees or entire forest stands from insects or diseases. The systems correlate edaphic, physiographic and climatic conditions and stand or individual tree characteristics with the frequency and intensity of pest outbreaks, so that forest managers can determine the probability of pest outbreak levels in a specified stand. These hazard rating systems can influence: 1) the alteration of long- and short-term stand prescriptions, 2) the development of priorities for intensive stand management, and 3) the development of priorities for intensive pest monitoring activities to detect incipient outbreaks, thereby reducing damage to the stand. The judicious use of risk-rating systems in stand management cannot always prevent outbreaks from occurring; however, some systems can reduce the severity of damage.

Individual tree risk-rating systems were first developed for the western pine beetle (Dunning 1978) and used tree characteristics (age, degree of dominance, a crown vigor). Miller and Keen (1960) elaborated on this work and developed an effective silvicultural treatment for east slope ponderosa and Jeffrey pine stands in California, Oregon, Washington, and Idaho by considering primarily age and crown vigor. This system works well in the Pacific Northwest and has been modified for use in other regions.

Recent research has emphasized hazard-rating forest stands. Douglas-fir tussock moth, gypsy moth, and southern pine beetle rating systems were developed through the accelerated research programs, but these systems have not been effectively transfered to user groups as of yet. Pilot projects are currently evaluating the effectiveness of stand hazard rating systems for these insects, as well as the red oak borer, littleleaf disease, annosus root rot, fusiform rust, and white pine blister rust (USDA-Forest Service 1979b).

SUMMARY

Forest managers rely heavily on the Forest Insect and Disease Management programs to survey Federal lands for possible insect and disease infestations. Survey programs employ a variety of techniques designed to detect major outbreaks as well as observe incipient population levels. Conventional survey techniques (sketch mapping and aerial photography) are useful, but are not able to detect pest problems until mortality and defoliation occur, thereby allowing pests to increase to outbreak levels before they are observed. In the past five (5) years, research efforts have emphasized ways to monitor incipient populations. This research has produced detection systems utilizing chemical attractants and should prove effective for identifying pre-outbreak populations. Methods to diagnose root diseases are still fairly primitive.

Population prediction models have been developed for many important insect species and should provide necessary input into impact prediction models. None of these models have been successfully tested under operational conditions. Epidemiological models that predict root disease spread rates are still undeveloped and will require extensive data collection efforts if they become operational.

Pest complexes have received very little consideration in past biological evaluations. The Region 5 Pest Damage Inventory has been developed to address problems caused by pest complexes.

There are two aspects of impact evaluation, ecological and socioeconomic, which are essential to understanding how forest pests affect natural and man-induced (or managed) systems. Methods to determine ecological impacts of major bark beetles and defoliator pests have improved significantly in the past decade. These methods are satisfactory for bark beetles but still need improvement for defoliators. Ecological impacts of diseases are not yet as clearly defined.

In forest systems, where the resources are being managed by multiple-use concepts, the social and economic impacts of pests must be considered into pest management decisions. Pest impacts on market resources are determined by using market values; however, estimating and subsequently quantifying the non-market impacts are hindered by a lack of information about how insect outbreaks affect recreation, wildlife, watershed, and fire hazards. The true social impacts of forest pests are seldom evaluated.

Timber stand and individual tree risk-rating systems for important forest pests are generally well developed and offer land managers the opportunity to allocate stand priority according to each stand's needs for pest prevention and monitoring activities. Few land managers have taken advantage of this opportunity. These rating systems have also contributed much of the information needed in the development of the silvicultural guidelines.

6.0 PREVENTION AND SUPPRESSION

The major objective of a pest management program is to keep losses due to pests within tolerable limits. The number of forest insects and diseases considered to be "pests" has expanded greatly in the past few decades with the growth in intensive forestry and the utilization of a wider variety of timber species. Silvicultural practices can be used for effective and long-lasting pest prevention. However, using them does not guarantee that outbreaks will not occur. In the event of an outbreak, suppression measures must often be taken that frequently require the application of chemical or biological control agents. Historically, forest pest management has been crisis-oriented. Broad-spectrum pesticides have been available to react to pest crises; but it is these chemicals which have produced unacceptable environmental problems. The development of chemical, biological, and silvicultural alternatives to broad-spectrum pesticides has been a low priority. Operational suppression projects have increasingly relied on conventional chemicals with biological control agents playing a relatively minor role (Table 6-1). During the 1970s, much more emphasis has been placed on the development of alternatives to conventional, broad-spectrum pesticides.

This chapter summarizes the forest pest prevention and suppression activities of the USDA-Forest Service. Research, development and management activities are described.

6.1 Chemical Methods

Pesticides have been the major tools used to control forest insects since the early 1900's. As a result of the environmental problems associated with persistent, broad-spectrum insecticides, e.g., chlorinated hydrocarbons, organophosphates, carbamates, and the consequent limitations placed on their use by the EPA, the need to develop alternative forms of direct control has increased greatly during the past ten years. The trend away from chemical pesticides is reflected in current USDA-Forest Service policy. However, the chemical industry has been uninterested in developing and registering unconventional chemicals (such as behavioral-modifying chemicals and insect growth regulators) for specific use in forestry since developmental costs are high and potential markets are limited. Consequently, the USDA-Forest Service has recently become more active in the development of such chemicals while continuing to screen agricultural chemicals for efficacy against forest pests and other non-target organisms.

TABLE 6-1. Operational use of biological, chemical, and mechanical/silvicultural methods (by acres) by or in cooperation with the USDA-Forest Service for selected forest insect pests, 1977-1979.[1]

	INSECT	REGION/AREA 1	2	3	4	5	6	SA	NA	TOTAL
BIOLOGICAL CONTROL	Gypsy moth	*	*	*	*	*	*	0	6,829	6,829
	Spruce budworm	*	*	*	*	*	*	*	21,848	21,848
	Western spruce budworm	0	0	0	0	0	0	*	*	0
	Mountain pine beetle	0	0	0	0	0	0	*	*	0
	Southern pine beetle	*	*	*	*	*	*	0	*	0
	TOTAL	0	0	0	0	0	0	0	28,677	28,677
CHEMICAL CONTROL	Gypsy moth	*	*	*	*	*	*	0	311,590	311,590
	Spruce budworm	*	*	*	*	*	*	*	4,837,642	4,837,642
	Western spruce budworm	140,000	0	0	0	0	451,601	*	*	591,601
	Mountain pine beetle	192	673,504	0	123	0	0	*	*	673,819
	Southern pine beetle	*	*	*	*	*	*	148,877	*	148,877
	TOTAL	140,192	673,504	0	123	0	451,601	148,877	5,149,232	6,563,529
SILVICULTURAL/ MECHANICAL	Gypsy moth	*	*	*	*	*	*	0	0	0
	Spruce budworm	*	*	*	*	*	*	*	1,501,850	1,501,850
	Western spruce budworm	0	0	0	0	0	0	*	*	0
	Mountain pine beetle	0	536,631	0	0	0	589	*	*	537,220
	Southern pine beetle	*	*	*	*	*	*	38,407,746	*	38,407,746
	TOTAL	0	536,631	0	0	0	589	38,407,746	1,501,850	2,039,070[2]

[1] Data are not available for Region 10.

[2] Data for SA consists of "acres protected" rather than treated; consequently these data are not included in the grand total.

* Species not normally found in this region/area.

Source: USDA-Forest Service, FI&DM, Rossyln, Virginia.

During the 1950's, insecticide research concentrated on efficacy studies of chlorinated hydrocarbons and other broad-spectrum, persistent pesticides and on formulation and application technology. Toxicity to non-target organisms and environmental persistence were largely ignored. Not until the late 1960's, were efforts at developing more selective insecticides and unconventional chemicals greatly accelerated. For western needs, most of this work is centered at the Pacific Southwest Experiment Station. Chemicals are screened at the Berkeley Laboratory and promising candidates are field-tested by personnel at the Davis Lab. In the South, a similar research program is ongoing at the Southeast Experiment Station's Research Triangle Park Laboratory. In contrast to the past, current investigations produce data on pesticide environmental impact in addition to efficacy estimates.

Conventional Chemicals

Chemical Bark Beetle Control: Conventional chemicals were first used to control bark beetles in the 1930's. Tree injections of copper sulfate solution were used operationally against mountain pine beetle between 1933-1936 (Klein 1978). Fuel oil solutions of ortho-dichlorobenzene (ODB) were sprayed to control mountain pine beetle throughout the 1940's and 1950's. The use of ethylene dibromide (EDB) for spruce beetle began in the early 1950's and soon replaced ODB for mountain pine beetle control, as well. EDB also became an established control spray for the western pine beetle but was replaced by lindane during the late 1960's. Lindane proved to be less expensive, was safer to handle, and had a longer residual life than EDB. EDB and lindane could be applied externally to the bark of standing or felled trees and greatly reduced the labor involved in bark peeling or burning. Today, EDB is used almost exclusively for the mountain pine beetle in Region 2, while lindane is still the primary chemical used for western pine beetle and southern pine beetle control in Region 5 and the Southeastern Area respectively. However, the long residual life of this chlorinated hydrocarbon which is, in part, responsible for its potent insecticidal properties, has also stimulated controversy as to its long-term effects on non-target organisms (Wood 1979, personal communication). Consequently, remedial chemical alternatives to lindane have been and are being developed through the Expanded Southern Pine Beetle Research and Application Program (ESBRAP) and at the Pacific Southwest Experiment Station.

Treatment of bark beetle-infested trees with conventional insecticides has been a common practice throughout Regions 1, 2, 5, and the Northeastern and Southeastern Areas between 1975-1978 (Table 6-2).

TABLE 6-2. Total acreage and/or trees treated with insecticides for bark beetle control by or in cooperation with the USDA-Forest Service, 1975-1978.[1]

INSECTICIDE	REGION/AREA 1	2	3	4	5	6	SA	NA	TOTAL
Lindane									
Acres	0	5	0	150	13,800	0	1,235	0	15,190
Trees	0	52,109	0	400	55,681	0	44,862	0	153,052
EDB									
Acres	0	0	0	0	0	0	0	0	0
Trees	0	321,258	0	0	0	0	0	0	321,258
Sevin-4-oil									
Acres	0	0	0	150	0	0	0	0	150
Trees	10,869	1,050	78	737	0	0	0	0	12,734
Dursban									
Acres	0	0	0	0	0	0	438	0	438
Trees	0	0	0	200	11	0	0	0	211
TOTAL									
Acres	0	5	0	300	13,800	0	1,673	0	15,778
Trees	10,869	374,417	78	1,337	55,692	0	44,862	0	487,255

[1] Data are not available for Region 10.

Source: USDA-Forest Service Pesticide-Use Reports, FI&DM, Rossyln, Virginia.

Researchers at the Intermountain Experiment Station have found Sevin-4 oil to be an effective prophylactic spray that can protect high value ponderosa pines from mountain pine beetle for approximately $5/tree. It has been used on a limited basis for this purpose in Regions 1, 2, 3, and 4. Dursban and lindane have also been used as prophylactic sprays for southern pine beetle.

The value of chemical bark beetle control has been a subject of intense controversy among forest entomologists. Since few crop protection effects have ever been shown, it is the opinion of some that silvicultural management is the only effective means of reducing bark beetle losses. However, others are quick to point out that the efficacy of silvicultural prevention measures have yet to be proven.

Chemical Lepidoptera Control: DDT comprised 84 percent of all aerially-applied insecticide used between 1945 and 1965 with over 25 million acres sprayed during this period (Table 6-3). Until the environmental side effects of this pesticide precipitated its cancellation, DDT was the primary insecticide used in control projects for eastern and western spruce budworm, Douglas-fir tussock moth, gypsy moth, hemlock looper, and pine butterfly.

In 1958, carbaryl (Sevin) began replacing DDT for gypsy moth control. Since 1972 it has been the primary chemical used by, or in cooperation with, USDA-Forest Service in gypsy moth control efforts (USDA-Forest Service 1974a). Carbaryl has also become the most widely used insecticide for eastern and western spruce budworms (Buffam 1979, personal communication). This chemical comprised 84 percent of all aerially-applied insecticides between 1975-1978 (Table 6-4). The low cost of carbaryl in comparison to other chemicals has contributed to its widespread use. However, carbaryl's toxic effects on honeybees, some aquatic organisms, and potentially human health, have precipitated the development of other, more selective and less residual compounds, such as acephate (Orthene) and trichlorfon (Dylox).

As can be seen in Table 6-3, mexacarbamate (Zectran) was used fairly extensively between 1971 and 1974. It was found to be effective at controlling eastern spruce budworm, with relatively little effect on non-target organisms. However, with its high production costs (approximately $35 per pound) and with markets limited to forest insect control, the product was no longer commercially attractive to industry. Consequently, production of mexacarbamate was terminated in the mid-1970s and it is no longer used.

TABLE 6-3. Forest area aerially sprayed with insecticides in the United States, 1945-1974, by year and material used.[1]

YEAR	DDT	CARBARYL	MEXACARBANATE	MALATHION	FENITROTHION	TRICHLORFON	DFTM VIRUS	GARDONA	LEAD ARSENATE	BACILLUS	TOTAL
1945	7,000	---	---	---	---	---	---	---	9,000	---	16,000
1946	64,000	---	---	---	---	---	---	---	---	---	64,000
1947	533,000	---	---	---	---	---	---	---	---	---	533,000
1948	218,000	---	---	---	---	---	---	---	---	---	218,000
1949	661,000	---	---	---	---	---	---	---	---	---	661,000
1950	1,548,000	---	---	---	---	---	---	---	---	---	1,548,000
1951	1,105,000	---	---	---	---	---	---	---	---	---	1,105,000
1952	880,000	---	---	---	---	---	---	---	---	---	880,000
1953	700,000	---	---	---	---	---	---	---	---	---	700,000
1954	1,733,000	---	---	---	---	---	---	---	---	---	1,733,000
1955	3,653,000	---	---	---	---	---	---	---	---	---	3,653,000
1956	2,306,000	---	---	---	---	---	---	---	---	---	2,306,000
1957	4,898,000	---	---	4,000	---	---	---	---	---	---	4,902,000
1958	1,773,000	---	---	---	---	---	---	---	---	---	1,773,000
1959	216,000	86,000	---	3,000	---	---	---	---	---	---	305,000
1960	430,000	11,000	---	1,000	---	---	4,000	---	---	---	446,000
1961	218,000	29,000	---	5,000	---	---	---	---	---	---	252,000
1962	1,592,000	31,000	---	---	---	---	---	---	---	---	1,623,000
1963	2,074,000	130,000	---	20,000	---	---	12,000	---	---	---	2,236,000
1964	632,000	97,000	---	161,000	---	---	---	---	---	2,000	892,000
1965	363,000	234,000	---	11,000	---	---	---	---	---	1,000	609,000
1966	---	275,000	5,000	143,000	---	---	---	---	---	---	423,000
1967	100,000	203,000	3,000	1,000	---	---	---	---	---	---	307,000
1968	---	201,000	7,000	7,000	10,000	39,000	---	---	---	---	264,000
1969	---	95,000	16,000	6,000	---	6,000	---	10,000	---	---	133,000
1970	---	233,000	---	5,000	212,000	3,000	---	3,000	---	---	456,000
1971	---	390,000	19,000	---	---	---	---	1,000	---	---	410,000
1972	---	172,000	500,000	13,000	---	3,000	---	---	---	2,000	690,000
1973	---	61,000	543,000	---	---	125,000	---	---	---	3,000	732,000
1974	425,000	90,000	470,000	---	---	77,000	---	---	---	15,000	1,077,000
	26,129,000	2,338,000	1,563,000	380,000	222,000	253,000	16,000	14,000	9,000	23,000	30,947,000

[1]modified from Miller & Committee 1975:170.

TABLE 6-4. Total forest lands (in acres) treated with aerially-applied insecticides by or in cooperation with the USDA-Forest Service, 1975-1989.[1]

	INSECTICIDE	REGION/AREA 1	2	3	4	5	6	SA	NA	TOTAL
NATIONAL FORESTS AND OTHER FEDERAL LANDS	DDT	28,104[2]	0	0	0	0	0	0	0	28,104
	Carbaryl	20	0	35,858	3,176	3,048	351,918	253	1,135,438	1,529,711
	Malathion	0	0	0	0	0	313,330	236	11,309	324,875
	Fenitrothion	0	0	0	0	0	11,454	0	0	11,454
	Trichlorfon	0	0	53,000	0	0	0	0	189,000	242,000
	Acephate	0	0	0	4,000	0	0	0	102,000	106,000
	SUBTOTAL	28,124	0	88,858	7,176	3,048	676,702	489	1,437,747	2,290,321
STATE AND PRIVATE LANDS	DDT	0	0	0	0	0	0	0	0	0
	Carbaryl	0	1,320	15	0	0	12,407	0	4,302,481	4,316,223
	Malathion	0	0	3	0	0	52,500	0	115	52,618
	Fenitrothion	0	0	0	0	0	0	0	6,480	6,480
	Trichlorfon	0	0	0	0	0	0	0	190,374	190,374
	Acephate	0	0	0	0	0	0	0	65,220	65,220
	SUBTOTAL	0	1,320	18	0	0	64,907	0	4,564,670	4,630,915
TOTAL FOREST LANDS	DDT	28,104[2]	0	0	0	0	0	0	0	34,979
	Carbaryl	20	1,320	35,873	3,176	3,048	364,325	253	5,437,919	5,845,934
	Malathion	0	0	3	0	0	365,830	236	11,424	379,162
	Fenitrothion	0	0	0	0	0	11,454	0	6,480	17,934
	Trichlorfon	0	0	53,000	0	0	0	0	379,374	432,374
	Acephate	0	0	0	4,000	0	0	0	167,220	171,220
	TOTAL	28,124	1,320	88,876	7,176	3,048	741,609	489	6,002,417	6,921,236

[1]Data obtained from USDA-Forest Service Pesticide-Use Reports, FI&DM, Rossyln, Virginia.

[2]DDT used in Region 1 during FY 1975 for Tussock Moth.

The regional use distribution of the major forest insecticides (other than Carbaryl) applied in aerial spray programs are also listed in Table 6-4. Combined, they only account for 16 percent of the national total of insecticides used in forestry.

During the past few years, the aerial application of pesticides has been concentrated in only a few areas. Eighty-seven percent of all forest pesticides have been used in the Northeast where eastern spruce budworm and gypsy moth are prominent pests. Another 10 percent were used in attempts to control the western spruce budworm in Region 6 (Table 6-1).

The use of chemicals for cone and seed insect control is routine seed orchard management today. In this para-agricultural situation, where crop values are high, the risk of insect damage is given as justification for the use of expensive insecticides on a regular basis. Insects have been known to destroy over 50 percent of the seed in some seed orchards (Barras 1979, personal communication). As can be seen from Table 6-5, 90 percent of all control work is done in the Southeastern Area where there exists over 6,000 acres of pine seed orchards. Most of these orchards are under State and private ownership. The major targets of insecticidal treatments in seed orchards are seed and cone moths, seedbugs and cone beetles. The most commonly-used insecticides include azinphosmethyl, malathion, dimethoate, carbaryl, and carbofuran (Table 6-5).

In general, chemical methods have been judged to be too costly to justify control efforts designed to reduce disease-caused losses under forest situations. Whereas insects may cause significant mortality and are often highly susceptible to pesticides, diseases usually cause less significant losses and are much more difficult to control with chemicals. Consequently, chemical treatments of diseases are limited to high value situations such as those which occur in nurseries and plantations.

Table 6-6 shows that 86 percent of all chemical control in nurseries took place in the Southeastern Area (74 percent) and the Northeastern Area (12 percent). Most of the efforts in the Southeast were directed at controllng fusiform rust in State and private nurseries. Fumigation to control damping-off fungi contributed to approximately 20 percent of the national effort.

Unconventional Chemicals

The potential usefulness of behavior-modifying chemicals (BMCs) and insect growth regulators (IGRs) as forest pest control agents has only recently been recognized by forest entomologists. This recognition has led to increased research concerning these substances, primarily through the Accelerated R&D Programs. However,

TABLE 6-5. Use of insecticides by Acre/Tree in seed orchards by the USDA-Forest Service, 1974-1979.[1] (A = Acre; T - Tree)

INSECTICIDE		REGION/AREA 1	2	3	4	5	6	SA	NA	TOTAL
Carbofuran	A							223	1	224
	T							7,580	60	7,640
Dimethoate	A		10			421		1,370	29	1,830
	T	60						121,720		121,780
Azinphosmethyl	A						10	128		138
	T							85,225		85,225
Malathion	A	28	83		8	2		2,739	115	2,975
	T							900	500	1,400
Thiodan	A								1	1
	T							1,040		1,040
Carbaryl	A		25					1,599		1,624
	T							1,500		1,500
Disulfotan	A							10		10
	T							14,850		14,850
Phorate	A							23		23
	T							17,200		17,200
Dursban	A							70		70
	T									0
Diazinon	A							125		125
	T							1,500		1,500
Dieldrin	A							5		5
	T									0
Disystox	A							100		100
	T									0
TOTALS	A	28	118	0	8	423	10	6,392	146	7,125
	T	60	0	0	0	0	0	251,545	560	252,165

[1]Data are not available for Region 10.

SOURCE: USDA-Forest Service Pesticide-Use Reports, FI&DM, Rossyln, Virginia.

TABLE 6-6. Chemical control of common nursery pests by the USDA-Forest Service, 1974-1978 (by acre).

TARGET	REGION/AREA 1	2	3	4	5	6	SA	NA	TOTAL
Fusiform Rust	0	0	0	0	0	0	3,858	0	3,858
Brown Spot Needle Blight	0	1	0	0	0	0	191	0	192
Needle Casts	0	1	0	0	20	0	0	66	87
Phomopsis Canker	0	166	0	0	0	0	0	0	166
Soil and Root Fungi	22	0	0	60	107	0	146	10	345
Damping-off	159	32	15	43	68	138	106	660	1,221
Cutworms	0	0	0	0	21	1	206	4	232
TOTALS	181	200	15	103	216	139	4,507	740	6,101

SOURCE: USDA-Forest Service Pesticide-Use Reports, FI&DM, Rossyln, Virginia.

their utilization in operational programs has only been on a limited basis.

BMCs are synthetic versions of insect pheromones that may be utilized as potent attractants, disruptants, or repellents. IGRs include analogues of insect developmental hormones that can seriously disrupt the target organism's developmental processes. Whereas most conventional pesticides exhibit toxic effects over a wide range of organisms, BMCs and IGRs have highly specific modes of action, affecting the target pest and having very little impact on non-target organisms.

Large industrial chemical firms have shown little interest in non-conventional chemical research and development activities for several reasons. Due to their high specificity, commercial markets for non-conventional chemicals are extremely limited. In addition, field efficacy is often much more difficult to determine and usually represents a much greater economic investment than similar determinations for conventional chemicals. In the face of these economic constraints, the USDA-Forest Service has taken a major role in the research and development of non-conventional chemicals. Unlike industry, the Forest Service considers that the environmental advantages inherent in these chemicals will help defray their high developmental costs.

Insect Growth Regulators

There are two groups of insect growth regulators: inhibitors of chitin biosynthesis and juvenile hormone analogues. Chitin inhibitors have several advantages over juvenile hormone analogues such as; 1) their greater stability when exposed to sunlight, and 2) their lower cost. Consequently, USDA-Forest Service research has concentrated on chitin inhibitors.

Diflurobenzuron (Dimilin), an inhibitor of chitin biosynthesis, is the only IGR registered for use against a forest insect (gypsy moth). Chitin is a major component of every insect's exoskeleton, consequently insects cannot survive without it. Diflurobenzuron's high efficacy and low cost have been adequately documented. However, because its human health effects are still in question, the EPA has limited its use to uninhabited areas only. Diflurobenzuron has been used operationally only during the past few years and usually has not involved more than 10,000 to 15,000 acres/year. Diflurobenzuron and three other inhibitors of chitin biosynthesis are currently being evaluated for their usefulness against spruce budworm under the auspices of the CANUSA program. This compound was also developed for use against the Douglas-fir tussock moth; however, its registration is not foreseen in the near future (Honing 1980, personal communication).

Much of the screening of unconventional chemicals has occurred at the Pacific Southwest Experiment Station, which has developed some promising IGRs. Although further research is needed to determine their potential, USDA-Forest Service research is being delayed temporarily as there is a fair chance that certain industrial firms may be willing to follow up with the necessary work on these promising compounds (Spada 1979, personal communication).

Behavior-modifying Chemicals

The three general strategies for the use of behavior-modifying chemicals in a prophylactic or suppressive mode for forest insects are: (1) Disruption - air permeation with aggregation pheromones (bark beetles) or sex pheromones (Lepidoptera) to prevent the insects from finding their hosts and/or mates; (2) Mass-trapping - bark beetles are attracted to an aggregation pheromone source where they are immobilized; and (3) Inhibition - repellent compounds are applied to, or in the vicinity of, host material which is subsequently left unattacked.

Disparlure, a synthetic gypsy moth sex attractant, has been subjected to extensive R&D efforts aimed at developing its potential as a mating disruptant but has not been successful on an operational basis to date. Ten thousand acres of forest in Pennsylvania were treated with micro-encapsulated disparlure in 1979 as part of the Gypsy Moth Retardation Pilot Project. However, the pheromone failed to reduce gypsy moth egg mass densities significantly in the treated areas (Yarger 1980, personal communication).

Tests using aerially applied, controlled-release formulations of pheromones have been conducted recently by Pacific Northwest Experiment Station researchers in an effort to disrupt mating in western pine shoot borer and Douglas-fir tussock moth. Shoot-borer damage reduction ranged from between 69-90 percent on ponderosa pine plantations in a pilot project during 1979. The technique also appears effective for tussock moth but will not be definitively tested until the next moth outbreak. Similar work is just getting underway with the western spruce budworm (Daterman 1979, personal communication). No similar research on spruce budworm in the East is being funded through CANUSA, although this strategy has excellent suppression potential.

Pheromone research on western bark beetles was conducted in the early 1970's through a cooperative effort by investigators at the University of California, Berkeley and the Pacific Southwest Experiment Station. Their efforts culminated in large-scale field tests involving the western pine beetle. Although no definitive crop protection effects were demonstrated, a theoretical and technological background was developed that has been extensively

utilized in later studies (Wood 1979).

Another large-scale field experiment to establish the efficacy of the western pine beetle pheromone is likely to be conducted in the near future. This pilot project would be administered jointly by FI&DM, Region 5, and the Pacific Southwest Experiment Station. If successful, it could lead to registration of the pheromone as an operational tool for prevention of tree mortality (Bedard 1979, personal communication).

Research on southern pine beetle pheromones has been ongoing since 1962 and was accelerated through the Expanded Southern Pine Beetle Research Program. However, it is not considered to be a high priority research problem at this time by ESPBRAP administrators since its potential for beetle suppression has yet to be adequately demonstrated (Coster 1980, personal communication).

Mass-trapping techniques for the smaller European elm bark beetle (a vector of Dutch elm disease) are well-developed but tree protection effects have yet to be demonstrated (Lyon 1979, personal communication).

Several BMCs have been developed which prevent bark beetle mass attack when applied to host material. Methylcyclohexanone has been studied extensively at the Intermountain Experiment Station. A projected pilot test in 1980 should determine its effectiveness in preventing Douglas-fir beetle from attacking wind-thrown timber (USDA-Forest Service 1979d). Endo-brevicomin and verbenone are being investigated for their potential to lower the attack rate of southern and western pine beetles on high value trees (Wood 1979, personal communication).

BMCs can be effective in minute concentrations and are essentially non-toxic compounds. These important attributes should favor their incorporation into future pest management programs. However, at this point, no pheromone suppression systems are in operational use for any major forest insect pests. In spite of the many difficulties encountered in financing research and development and showing crop protection effects, the future of BMCs is promising.

Summary of Chemical Methods

Conventional chemicals have been, and still are, the primary tools used in forest pest control. However, chemical research in forest pest management today emphasizes less ecologically-disruptive compounds. Such compounds include conventional chemicals with more selective toxicities and shorter residual lives then conventional chemicals now in use, and unconventional chemicals that have very little effect on non-target organisms. Research began

to explore non-target effects of pesticides to a much greater extent during the 1970's than during previous years.

Lindane and ethylene dibromide are currently the most-widely used chemicals in bark beetle control. Prophylactic sprays to prevent bark beetles from attacking high value trees have been recently developed for mountain and southern pine beetles and are now used operationally.

Carbaryl has replaced DDT as the primary insecticide used to control major forest defoliators. Although it is considered environmentally safer than DDT, enough controversy has surrounded its use to warrant the development of alternative insecticides. Such work has resulted in the registration of several new insecticides, and in efficacy and environmental impact data for several others. The Accelerated R&D Programs played a major role in developing alternative tools for insect suppression.

The major uses of forest pesticides in recent years has been on State and private lands in the East where spruce budworm, gypsy moth and southern pine beetle have been epidemic.

Over 90 percent of all chemical applications for seed orchard insect control occurred on a routine basis in the South where pine seed orchards comprise a major industry.

Chemical control of forest diseases is not generally considered feasible except when high value resources are threatened. Over 70 percent of the chemicals applied to control nursery diseases occurred in the South where fusiform rust still demands intensive control efforts.

Unconventional chemicals (pheromones and insect growth regulators) have seen a tremendous rise in popularity during the past decade. This popularity is based primarily on their low level of impact on non-target organisms, in an era when environmental hazards from toxic substances are part of pest management policy. The chemical industry's reluctance to develop materials with such limited markets has placed much of burden to develop alternative suppression tools on the USDA-Forest Service.

Recent advances in the development of pheromone control have come through research by the Accelerated R&D Programs. Pheromone suppression systems have been developed for gypsy moth, Douglas-fir tussock moth and western pine shoot borer. Currently, none of these systems are used on an operational basis. Bark beetle pheromone suppression systems are much less developed.

The only insect growth regulator that has been fully developed and registered has been diflurobenzuron (Dimilin). This compound has been registered for use against gypsy moth and is being developed for several other important defoliators. It is inexpensive and biologically effective but its questionable human health effects have limited its application to uninhabited areas.

6.2 Biological Control Methods

Biological control strategies for forest pests consist of two major categories: 1) microbial applications, and 2) augmentation or release of predators and/or parasites. As with non-conventional chemicals, the major advantages of biological control strategies arise from their minimal effects on non-target organisms.

The microbials most commonly used in forest pest management are viruses and bacteria. These insect pathogens can cause epizootics within a pest population that result in the outbreak's decline. Aerial application of viruses often attempts to prematurely initiate an epizootic during the initial stages of an outbreak before significant damage has occurred; in contrast, bacteria are commonly used to protect threatened foliage through feeding inhibition.

Bacillus thuringiensis (BT), a bacterium pathenogenic to many Lepidoptera, was field tested against the Douglas-fir tussock moth in 1973 and is now registered for use by the EPA. A series of pilot projects during the past 6 years developed operational control procedures and obtained registrations for the use of BT against gypsy moth and spruce budworm. The Northeast Experiment Station is currently undertaking research on refining techniques of BT formulation and application against gypsy moth. The results of a 1979 pilot project indicate successful control rates (Yarger 1980, personal communication). Similar research is being funded through CANUSA for spruce budworms. At present, high production and formulation costs have restricted the application of BT to high value resources in environmentally-sensitive areas (USDA-Forest Service 1979).

Operational procedures have been developed and registrations obtained for nucleopolyhedrosis viruses (NPV) to control the gypsy moth and the Douglas-fir tussock moth. When used against the gypsy moth in a 1979 pilot project, NPV failed to reduce gypsy moth population within a 5,000-acre treatment (Yarger 1980, personal communication). In order to be prepared for the next tussock moth outbreak, the tussock moth virus must be produced in large quantities and stockpiled. However, the Forest Service has had problems in trying to find an industrial firm to produce it for a reasonable price (Buffam 1980, personal communication).

Consequently, the Forest Service may have to begin producing its own virus (Honing 1980, personal communication). Most research on viruses is conducted at experiment stations in the Pacific Northwest and the Northeast.

Nematodes, microsporida, fungi, and other microbes have not been investigated sufficiently to reveal their promise (Wood 1979, personal communication). Research on fungi (Entomophtora) is being funded for its potential use against spruce budworm through CANUSA.

Microbial research and development programs have been beset by many application and formulation problems that have led to erratic results. For instance, production and application costs tend to be significantly higher than for conventional chemicals. Like unconventional chemicals, however, their insignificant effects on non-target organisms may justify their increased costs. In addition, as production and application techniques are refined, these costs should decrease accordingly. During the 1970's, research and development of microbial insecticides have increased dramatically. However, their operational use is relatively insignificant when compared to the use of chemicals (Table 6-1).

Predators and parasites have often been cited as major influences in regulating pest populations. Introductions of predators and parasites for imported pests, i.e., gypsy moth, larch casebearer, hold great potential for restoring natural control mechanisms. Such natural enemy importation strategies hold much less potential for native pests, i.e., spruce budworm, Douglas-fir tussock moth. However, augmentation of existing natural enemy complexes through improving predator or parasite habitat may further the stabilization of both native and imported pest populations.

The release of predators and parasites for biological control of forest pests has been only of peripheral concern to the USDA-Forest Service (Drooz, Dahlsten 1979, personal communication). Most of the work with predators and parasites has been either through research or administrative studies. The Bureau of Entomology and Plant Quarantine played a large role in the successful importation of gypsy moth natural enemies. During the late 1950's, the USDA-Forest Service introduced an exotic predator to control the balsam woolly aphid but failed to establish it successfully. Parasitic wasps of the European pine shoot moth were established in the north-central states during the 1950's and still have some effect there (Drooz 1979, personal communication).

Today, research on the use of parasites and predators to control insect pests is still not a major emphasis in FI&DR, although some studies are being conducted. Over the past few years, personnel at the Pacific Northwest Experiment Station and Region 1 have

released larch casebearer parasites in Washington, Idaho, and Montana. Three parasitic wasps were successfully established in Montana but not in Washington (Ryan 1979, personal communication). Northeast Experiment Station personnel attempted to establish parasites of the larch sawfly in New York and Pennsylvania. This project was recently halted when host resistance was found to significantly reduce the parasite's effectiveness (although monitoring continues) (USDA-Forest Service 1979d). Similar work on parasites of elm spanworm and fall cankerworm at the Southeastern Experiment Station has been terminated due to a lack of funds (Drooz 1979, personal communication). A new program is now gearing up for biological control of the introduced pine sawfly in the Southeast. The program will utilize sawfly parasites which have been reared by the USDA-Forest Service (Ibid).

At the Northeast Experiment Station, there is continuing research on the biology of gypsy moth parasites and their importance as biological control agents. In an effort to augment the effectiveness of small mammalian gypsy moth predators, techniques are being developed to monitor their populations and to supplement their food supplies artificially (USDA-Forest Service 1979d). Overall, importation and augmentation of natural enemies has contributed little toward solving forest pest management problems.

In the past decade, research has intensified to evaluate the role of natural enemies in maintaining destructive insects at endemic levels. This information is needed to assess the potentially negative impacts of control treatments that inadvertantly destroy natural enemies. This type of work is currently being conducted for southern pine beetle, western spruce budworm, Douglas-fir tussock moth, and cone and seed insects.

Biological control measures should receive increased attention during the 1980's to conform with the concept of integrated pest management as a basis for USDA-Forest Service pest management policy.

Summary of Biological Control Methods

Biological control strategies, like non-conventional chemicals, have much less of a negative impact on non-target organisms than conventional chemicals. However, they play a minor role in current operational forest pest management programs.

Microbial agents are receiving a great deal of research and development attention in current Forest Service research programs. Bacillus thuringiensis (BT) has been registered for use against numerous important forest defoliators. However, its high costs usually limit its use to protection of high value resources in environmentally-sensitive areas. Viruses have been registered for

use against gypsy moth and Douglas-fir tussock moth. Although the tussock moth virus is considered to be a highly valuable suppression tool against this insect, there are insufficient quantities available to control an outbreak in the near future. Most of the significant work on microbial control research has been supported through the Accelerated R&D Programs.

The release of predators and parasites for the biological control of forest pests has generally been of peripheral concern in the USDA-Forest Service. The only significant accomplishments of natural enemy release programs have been with gypsy moth and larch casebearer, and even these undertakings have been only partially successful.

Research on importation and/or augmentation of natural enemies is presently a low priority topic for forest pests. The minimal work accomplished in the past has produced few viable accomplishments and the low level of past accomplishments contributes to the view that these methods have little potential for the future.

6.3 Silvicultural Methods

Management of forest insect pests through silvicultural methods is one of the most viable methods of forest protection. Many silvicultural guidelines exist which enable forest land managers to consider treatments that will increase growth and yield while decreasing the stands' susceptibility to insects and diseases. Stand composition, spacing, and age class distribution can be influenced by choice of seed and planting stock, regulation of initial planting density, and by regeneration cuttings and thinnings. Pest problems can be prevented or reduced by sanitation and pre-salvage cuttings.

The potential for effective pest management through silvicultural means has not been realized because of numerous basic problems, which included: (a) lack of sufficient knowledge on which to base stand prescriptions, (b) a huge surplus of unmanaged forest lands in which intensive silvicultural management for pests alone would be uneconomical, (c) USDA-Forest Service cost-sharing policies which did little to encourage silvicultural pest management, (d) an absence of concerted effort to transfer silvicultural management technology from researchers to land managers, and (e) an over-reliance on pesticide-related control techniques that created an apathetic attitude in relation to silvicultural management.

At present, improvement in each of the basic problems listed above is being remedied. Research in the hazard rating of stands and genetically-induced resistance to disease pests, together with field tests to determine the value of various silvicultural practices in pest management, have greatly contributed to the

available knowledge in these areas.

With increased demands for timber, more stands are being managed and opportunities for silvicultural treatments are becoming more feasible. Furthermore, one of the policies that prohibited FI&DM funds to be used for preventive thinning purposes has been changed and limited funds are now available for silvicultural pest prevention work.

Efforts by FI&DM personnel to incorporate silvicultural methods into long-range planning on National Forests have increased markedly in the past year (Buffam 1980, personal communication). New regulations promulgated by the National Forest Management Act stipulate that forest pests be considered in long-range planning and that integrated pest management concepts be implemented to control the pest species.

Little data are available on the extent to which silvicultural practices are utilized by the USDA-Forest Service to prevent insect and disease problems. When applied, silvicultural methods of forest pest management are usually part of timber management activities. Silviculturists may take insects and diseases into consideration when developing stand prescriptions and when entering a stand to cut or thin. Consequently, when forest pests are given such consideration, the resulting activities would not be reported as "pest management."

Particular Silvicultural Methods

The remaining part of this chapter briefly surveys the major methods utilized in silvicultural pest management.

Use of Improved Planting Stock: Growing trees that are genetically resistant to pests can often prevent future problems from occurring. Resistant genotypes can be obtained through: (1) selection of superior seed trees in the field; (2) screening for pest resistance; and (3) breeding resistant genotypes. Although breeding is the most efficient method of producing resistant genotypes, it also includes the risk that the strain resistant to one pest may be extremely susceptible to another unrelated pest, or that resistance may only exist for a narrowly-defined range of pest genotypes.

USDA-Forest Service disease resistance screening centers are located in North Carolina, Wisconsin, and Oregon. In North Carolina, over 13,000 southern pine seedlings are tested annually for resistance to fusiform rust. Those exhibiting rust resistance are used to establish seed orchards (Anderson 1979, personal communication). White pines are screened for resistance to white pine blister rust at the Wisconsin and Oregon locations (USDA-

Forest Service 1979d). In cooperation with resistance breeding programs, these screening centers are significantly reducing the time necessary to develop resistant stock. At the Northcentral Experiment Station, over 41 species or varieties of hard pines are being screened for resistance to the European strain of scleroderris canker (Nicholls 1979, personal communication). At the Northeast Experiment Station, screening programs are searching for stock resistant to elm phloem necrosis, decay, and air pollution (USDA-Forest Service 1979d).

Investigations of blister rust resistance in western white pines have been conducted for approximately 28 years. They led to the establishment of breeding programs at the Intermountain Experiment Station in 1960. Several seed orchards have now been established that are mass-producing partially disease resistant stock (Hoff and McDonald 1975). Although a sugar pine resistant stock was supposedly developed in California, it was not successfully outplanted because resistance broke down within a few years (Parmeter 1979, personal communication). Breeding programs also exist at the Southern Experiment Station to develop southern pines resistant to fusiform rust and brown-spot needle blight. Significant progress has already been made in both of these areas (USDA-Forest Service 1979e).

Breeding programs to produce insect resistant genotypes have been limited to pests of minor significance such as pine reproduction weevil and larch casebearer. This area of research has not been investigated sufficiently enough to make any conclusions on the viability of this approach.

Use of Resistant Species: When selecting planting stock for a high-risk site, the use of species resistant to a threatening pest is often a management alternative. Fitting the species to the site is one of the most common and effective silvicultural techniques for preventing pest damage. For instance, loblolly pine and hardwood species are recommended substitutes for shortleaf pine on sites with high littleleaf disease risk. Since dwarf mistletoe exhibits narrow host specificity, it has been standard practice to encourage regeneration of a species not found in the infected overstory (USDA-Forest Service 1977d). Many other similar cases exist.

Sanitation-Salvage Cuts: Sanitation-salvage cuts are conducted in areas where the removal of disease-infected or insect-infested trees may help retard the spread of a particular pest within a treated stand. During improvement cuts, overstory trees infected with dwarf mistletoe are often removed from adequately stocked stands that are only lightly infected in order to prevent mistletoe seeds in the overstory from infecting nearby understory trees. In cutting mistletoe-infected stands, it has become standard

practice to place the boundaries of clearcuts at least 50-75 feet beyond the margin of the infected stand if the stand is to be regenerated with a susceptible species. This procedure insures that mistletoe seeds originating in the surrounding overstory will not infect the subsequent regeneration in the clear-cut (USDA-Forest Service 1977). Similarly, uninfected trees are given priority when deciding on individuals to leave as seed trees or overstory shelterwood. Diseased trees not only pose an infection hazard to the subsequent regeneration but also may produce lower quality seed. These methods are used widely throughout the western regions.

Researchers at the Pacific Southwest and the Rocky Mountain Experiment Stations are continually developing methods for improved control of dwarf mistletoe through silviculture. A recent Forest Service symposium on dwarf mistletoe control presented many District and Forest silviculturists with an updated version of the "state-of-the-art" in mistletoe control through forest management. The proceedings from this symposium have been distributed to forest land managers in many areas where mistletoe is a problem (Wicker 1979, personal communication). However, adequate silvicultural management schemes have only been developed for a handful of conifer species (Dooling 1980, personal communication).

Control of active root disease centers often necessitates that a buffer strip around the disease center be clearcut. Guidelines for buffer strip widths have been developed for oak wilt (USDA-Forest Service 1972b), laminated root rot, and black stain root disease (Byler et al. 1979). In all cases, recommendations were made to replant with non-susceptible species. Operational use of these methods occurs on a very localized basis.

When faced with a large bark beetle outbreak, sanitation salvage measures are often conducted. Salvage efforts are only suitable in areas with good road accessibility since the infested trees must be removed from the area before the developing brood matures and emerges to attack the stand. This method is one of the oldest and most widespread responses to bark beetle outbreaks.

Thinning and Selective Cutting: Forest stands are thinned or cut for a multitude of reasons, including the prevention of pest-caused losses. Stocking level reduction, removal of overmature timber, and selective cutting of pest-susceptible species have all been suggested as potential pest prevention strategies. However, operational projects to demonstrate the economic efficacy of silvicultural pest management practices have only been initiated during the past few years.

Pilot projects are now underway to demonstrate the effectiveness of preventive thinning to control mountain pine beetle (Regions 1, 2) and spruce beetle (Region 10), and selective cutting (favoring spruce over balsam fir) to control spruce budworm (NA) (USDA-Forest Service 1979d). Other projects are evaluating the effectiveness of thinning to various stocking levels as a control for dwarf mistletoe in true fir (Region 5), and a combination of thinning and pruning to control white pine blister rust. The effectiveness of these projects at preventing pest outbreaks will not be known for some time.

Sanitation efforts are often rendered more cost-effective by incorporating them into regular thinning schedules. Except in the cases of root disease, innoculum in the residual stand may be effectively reduced in this way. The remaining trees may also harbor disease-resistant genes that can be passed on to future generations through natural reproduction. FI&DM maintains a funding program designed to encourage Federal and State land managers to incorporate sanitation thinning for dwarf mistletoe into their management plans.

While silvicultural guidelines for the management of many important forest insect pests have been developed through the Accelerated R&D programs, more work needs to be done for forest diseases, which have not been subject to as intensive R&D programs.

Pruning: Pruning infected branches is a very effective but expensive method of disease control. Its use is limited to intensive management situations and high value shade or ornamental trees. Deadwood pruning is undertaken as part of large scale Dutch elm disease control programs and is designed to remove bark beetle-infested wood from otherwise healthy elms (Minnesota Dept. of Resources, 1979). Pruning of dwarf mistletoe infections is generally limited to recreational areas where there is a potential physical safety hazard and damage to aesthetic values. Pruning in seed orchards and plantations is an important part of many rust and canker control programs.

Control of Alternate Hosts: In the case of some rust diseases, problems are sometimes reduced through removal of alternate hosts from in and around the stand. Elimination of *Ribes* sp. was practiced extensively for decades and was the major thrust in white pine blister rust control programs. Except for plantations, the practice has been phased out over the past 25 years as a result of numerous studies that have found it not to be cost-effective (Parmeter 1979, personal communication).

Prescribed Fire. Prescribed burning is one of the most effective methods for controlling brown-spot needle blight in longleaf pine. Where longleaf pine is to be naturally regenerated, prescribed burns are conducted during the autumn, before seedfall. These burns destroy diseased needles and reduce the amount of innocula available to infect the new seedlings. Fires are conducted during the dormant season of the crop trees in order to leave the terminal leaders unharmed (Childs et al. 1971). Prescribed fire is sometimes used to reduce disease innocula on sites with high annosus root rot hazard and has also been used to remove non-merchantable trees infected with dwarf mistletoe when complete clearing is desirable (Parmeter 1979, personal communication).

Summary of Silvicultural Methods

Management of forest insect pests through silvicultural means is the most viable method of forest protection. Opportunities for silvicultural pest management arise in planting, thinning, cutting procedures, and controlled burning. Silvicultural accomplishments in the Forest Service do not separate pest management silvicultural activities from those done for timber production or other purposes. Thus, it is very difficult to determine the extent of pest prevention through silvicultural methods that are used on the National Forests. Law and policy changes may pave the way for significant increases in silvicultural pest management activities by requiring that pest considerations be addressed during forest planning and by providing funds for silvicultural pest prevention activities.

Numerous stand hazard rating systems have been developed during the past few years that contained the baseline information used in the preparation of silvicultural pest management guidelines. Much more of this information is needed, especially for root diseases, if the hazard rating systems are to be effective operationally.

Sanitation cuttings are widely utilized to control dwarf mistletoe, root diseases and bark beetles. Thinning and selective cutting procedures have been devised for the management of a number of bark beetles, defoliators and diseases. A number of these procedures are currently being pilot-tested.

In disease management, breeding and screening for rust-resistant pines have reduced the hazards of fusiform rust and white pine blister rust in intensively managed stands. Research in this area has been extended to several other diseases.

7.0 DEVELOPMENT AND IMPLEMENTATION OF INTEGRATED FOREST PEST MANAGEMENT SYSTEMS

7.1 Integrated Forest Pest Management Systems

Management of forest pests embodies many of the same general concepts as those developed for agriculture. However, forest ecosystems require that agricultural pest management concepts and strategies be expanded considerably in order to adequately address the complexities involved in managing diverse forest ecosystems. Forest ecosystems are much more complex and diverse than agricultural ecosystems. Consequently, any given manipulation of a forest system will affect a correspondingly larger number of organisms and outputs. The rotation length of crops in forestry is many times greater than that in agriculture. This requires planning horizons in forestry to encompass much longer timespans than those in agricultural plans. Also the effects of management-induced alterations in the forest ecosystem will remain for a longer period of time. Unlike agricultural crops, forests are often managed for a multiplicity of management objectives. Consequently, forest pest management decision-making processes are considerably more complicated. The additional social, economic and legal constraints placed on forest pest managers further compound the tradeoffs to be considered by the decision-makers.

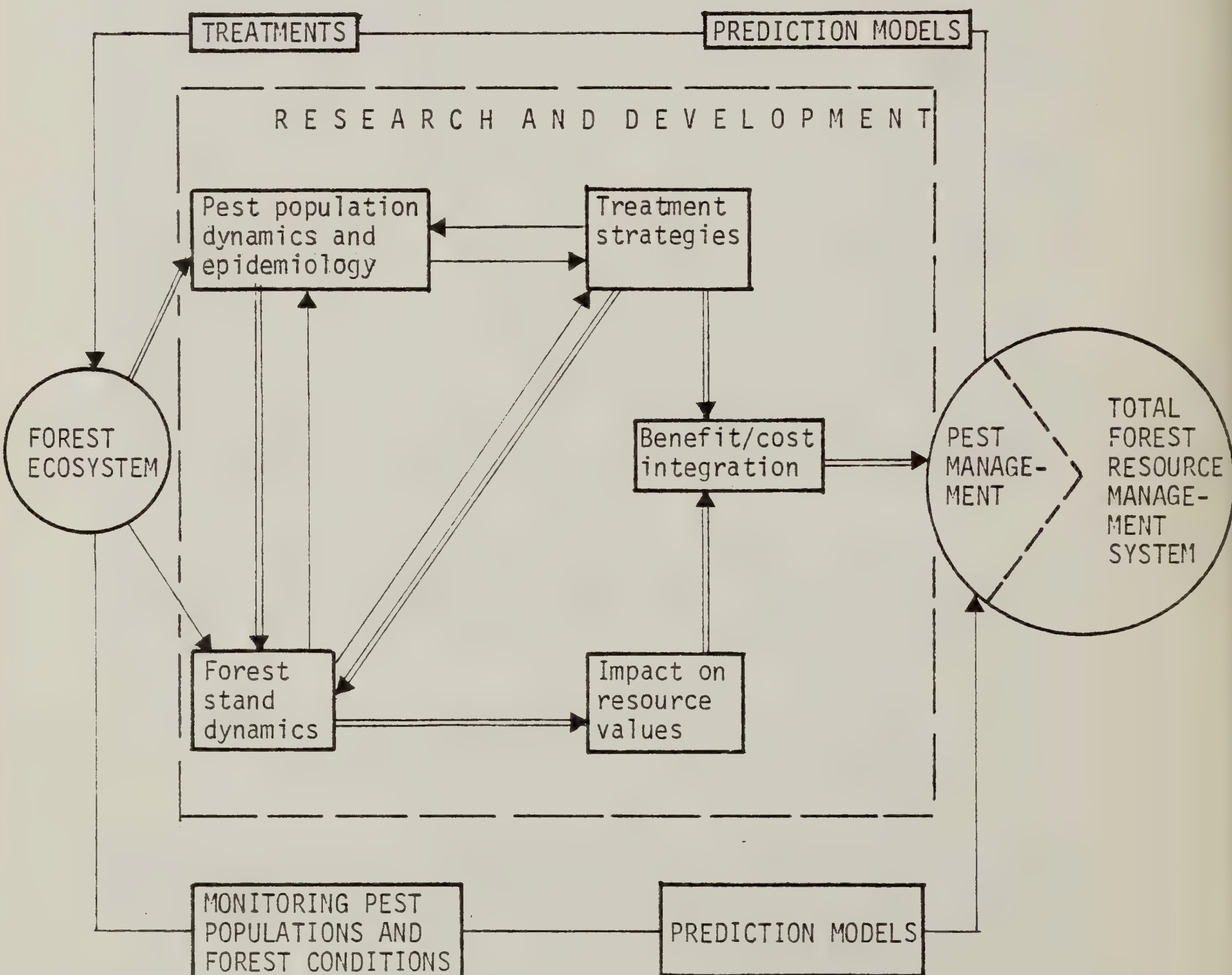
USDA-Forest Service policy recently has embraced an integrated pest management systems approach in their pest research and pest management programs. The concept of integrated pest managment (IPM) was first developd to address agricultural pest problems. Way (1977) defined it as:

> "...the balanced use of such measures, cultural, biological and chemical, as are most appropriate to a particular situation in light of careful study of all factors involved."

This concept has had to expand to address the more complicated problems confronting forestry with the development of a "systems approach" to forest pest management (Wood 1979, summarized in Waters and Stark, 1980).

A common misconception lies in the belief that the development and use of alternative control measures is the essence of IPM and that the "careful study of all factors involved" is of secondary importance. However, as can be seen in Figure 7-1, the general model structure of a forest pest management system actually emphasizes survey and evaluation procedures.

FIGURE 7-1. Model structure of a forest pest management system. The research and development phase is shown inside the dotted lines and the operational phase outside the dotted lines. (From Waters and Ewing, 1975).



Monitoring of pest populations and stand dynamics provides data for population prediction models as part of the biological evaluation process. These data are used as the basis for pest injury predictions which are then translated into impact estimates that will vary greatly, depending on the objectives of each forest resource management system. Social, environmental and economic benefits are then weighed against the social, environmental and economic costs of various treatments in order to identify a set of treatment strategies that will optimize resource outputs. Historically, consideration of alternatives has focused almost solely on timber and wood product values with costs being given as lost opportunity costs of not harvesting the timber.

The ultimate goal IPM policy is to have operational pest management systems established for all major forest pests of immediate or potential significance. This is presently an over-optimistic goal. Therefore, priority has been assigned to the development of IPM systems for the forest pests of major economic significance on a national scale, i.e., Douglas-fir tussock moth, gypsy moth, spruce budworms, and southern pine beetle.

7.2 Development and Testing of Advanced Pest Management Technology

Significant improvements have been made in many aspects of forest pest management systems during the past decade. Much of this progress can be traced to intensive, large scale programs and projects. The USDA-Accelerated Research and Development Programs have pulled together a substantial amount of potentially valuable, but untested pest management technology. With pilot projects and demonstration areas to refine and demonstrate the effectiveness of these new techniques, the chances of their implementation on an operational basis in the near future have been greatly improved. These new and apparently effective types of programs and projects are described below.

Accelerated Research and Development Programs

For years, Forest Service pest management research consisted of groups of scientists working on specific projects dealing with forest insects and diseases. Through these projects, much information was compiled about basic biology, ecological relationships, and control techniques. Yet it was difficult to determine how all these research projects could be unified to meet forest management objectives of preventing, controlling, and suppressing pest populations in order to reduce overall losses caused by insects and diseases.

In the early 1970's, the Nation's forests were subjected to major outbreaks of southern pine beetle, Douglas-fir tussock moth, and gypsy moth. Existing management and research efforts were not adequate to manage these pests successfully and it became apparent that a new approach was needed to develop the necessary technology to control these serious pests. An intensive, short-term, research, development, and application methodology was initiated under the aegis of the USDA-Secretary's Office, with four USDA agencies, including the Forest Service, participating with states and universities. It was known as the USDA Combined Forest Pest Research and Development Program (CFPRDP). (The organization of this CFPRDP is discussed in Section 3.1 of this report). The program began with the Douglas-fir tussock moth, gypsy moth, and southern pine beetle, but as the Douglas-fir tussock moth and gypsy moth programs ended, program emphasis shifted to eastern and western spruce budworms.

The new programs set forth a novel approach to insect and disease research. Rather than working to develop blocks of knowledge in certain disciplines, research efforts were goal-oriented: to produce alternative methodologies to those that existed and to develop a systems, or integrated, approach to forest pest problems. Program managers defined problems that they, with input from other scientists, felt needed answering. This was somewhat of a change from standard research procedures, which allows individual scientists to develop their own priorities through experiment station research work units.

The programs are also funded non-traditionally. Funding was generally adequate while the programs were operational. However, when particular programs end, funds may not be available to solve unanswered questions, or to publish and distribute the resulting literature.

These programs produced many accomplishments in the area of survey, evaluation, prevention, suppression and pest management systems development (see Table 7-1). Such systems packages for Douglas-fir tussock moth and mountain pine beetle* have been developed, but still await testing and refining. Other similar systems are nearing completion for southern pine beetle and gypsy moth (Waters and Stark 1980). However, no IPM system packages have proven operationally effective to date.

Appendix tables 4 through 9 summarize the information needed to develop pest management systems for a representative sample of forest pests: 1) at the onset of 1970's, and 2) at the present time. In general, the pests that have been subjected to rigorous

*Research conducted through a National Science Foundation/
Environmental Protection Agency Program

TABLE 7-1. Some general accomplishments arising out of the accelerated research and development programs

Accelerated R&D Program	Accomplishments
Gypsy moth	Egg mass sampling plan developed Virus registered with EPA Several additional pesticides registered Schemes developed to predict defoliation & mortality probabilities Imported parasites reared and widely released Sex pheromone evaluated for its usefulness as a control agent IPM system developed
Douglas-fir tussock moth	Larval sampling methods developed for low population levels Pheromone detection system developed Stand hazard rating system developed Population outbreak model developed Natural enemies evaluated as control agents BT and virus registered for use Dylox and Sevin registered for use Field safety tests conducted for Orthene & Dimilin Aerial spray technology improved IPM system developed
Southern pine beetle	Sampling methods and predictive models developed for estimating population and damage trends Aerial survey & navigation system improved Stand hazard rating systems developed 29 insecticides screened for contact toxicity Efficacy data determined for Dursban, Reldan, and Sumithion Dursban registered for use Refined impact evaluation systems developed Model developed for projecting future damage levels Utilization guidelines developed for beetle-killed timber IPM system developed
Spruce budworms[1]	Comprehensive spruce budworm bibliography published

[1] Program initiated in 1978; consequently it is too soon to see any accomplishments based on in-depth research.

R&D programs, i.e., Douglas-fir tussock moth, southern pine beetle, mountain pine beetle, have fewer remaining research needs than the other, less intensively researched pests, i.e., root diseases, eastern spruce budworms, and to a lesser extent, dwarf mistletoes.

Refinements in the newly developed IPM systems and refinement of the systems continues at a slower pace through normal FI&DR channels. Table 7-2 presents a national overview of current USDA-Forest Service forest pest research topics. Although discussions in this text have been limited to a few major pest species, FI&DR is continually researching other pests of local or potential importance as shown in the table. Methodologies for survey, evaluation, prevention and suppression of major insects and diseases will undoubtedly facilitate the development of pest management systems for less important pests.

In order to implement newly developed pest management concepts and strategies, the new information must be presented to users in an understandable and convincing form. The need for technology transfer activities has been intensified by the new information made available through the CFPRDP. "Technology transfer teams" have been initiated as part of the Expanded Southern Pine Beetle Research and Application Program (USDA-Forest Service 1979h). The functions of these teams are to: 1) review research in their respective areas, 2) identify additional research and/or application studies needed to facilitate implementation, 3) seek out opportunities for demonstrating, testing, and implementing research, and 4) summarize their recommendations in action plans aimed at accomplishing technology transfer.

The Douglas-Fir Tussock Moth Program had approximately $500,000 budgeted for technology transfer activities. With these funds, a series of publications, e.g., "how to" handbooks, technical bulletins, and newsletters, were produced while workshops and symposia helped stimulate communication among researchers and between researchers and managers. Similar technology transfer activities were part of the Gypsy Moth Program. A major thrust of CANUSA, thus far, has been to publish state-of-the-art information on budworm biology and control. Technology transfer activities are not unique to the Accelerated R&D Programs but have been incorporated into FI&DR and FI&DM programs around the country. An Office of Technology Transfer has recently been established in the USDA-Forest Service to further these activities. The critical linkage between research and managers has not developed to its full potential.

TABLE 7-2. A summary of USDA-Forest Service research underway during 1979 (abbreviations used listed on following page).

Experiment Stations

		SO	SE	NE	NC	RM	INT	PSW	PNW	FPL
SURVEY DETECTION EVALUATION	I				PI			WPB, MPB	WSBD	
	D		DY		G					
IMPACT ASSESSMENT	I	CSI	S&C	SBD		MPB, WSBD	RLI		DFTM, SSW, WSBD, INM, BWA	
	D	CSD		AP	SC, HD	DM	ARR, AM, PW		DY, AP	
GENERAL BIOLOGY	I	ST	S&C	GM, HI, HS&C			RLI			
	D	LOD	S&C, MY, PC	OB, AM, EPN, DY, AP, OW	SC, PD, ND		ND	ND, OD, DM	MY	WPF
POPULATION DYNAMICS	I		SPB		G		MPB, LC	WPB	DFTM, WSBD	
	D				SC, PD		AM, PW			
PEST/HOST RELATION-SHIPS	I	SPB		GM, MCB	FTC, SBD			WPB, FE		
	D			DDD						
PEST MGMT. SYSTEMS	I			GM, SB					WSBD	
	D	BSHB		DED	SC, PD					
PEST MGMT STRATEGIES GENERAL	I	WDB, CSI	S&C, BB	HI	PI, PLI	SWPTM, IPS, DFTM		S&C, WPB, MPB	DFTM	ST
	D	DY, CSD	PC, ND	DED, DY, HD		ND	DM, RP	ND		DY
CHEMICAL	I	ST, WRD	S&C, SPB, BTB, IPS, PW, FC, NPTM, BWA					WPB, MPB, DFTM, ST, WSBD, S&C, LNM, DT	WSBD	
	D		FR, BSHB	DLD	SC, HD	CFD		ND	FA, DM	
SILVICULTURAL	I	SPB		SB, GM			MPB		DFTM, WSBD	
	D			DY	SC	DM	WPBR	DM		
BIOLOGICAL	I	SPB	S&C, FC, ES LS	GM					LC, DFTM	
	D								LRR	
MICROBIAL	I	SPB		GM, NS, SBD					DFTM, WSBD	
	D									
BEHAVIOR MODIFYING CHEMICALS	I	CW		GM			DFB	WPB	DFTM, WSBD, WPSB	
	D			DED						
GENETICS	I				FTC, SBD	G	LC			
	D	FR	FR	EPN, DY, AP, CB	SC		WPBR			

Source: 1979 Research Attainment Reports for each Experiment Station.

I = Insect, D = Disease

TABLE 7-2, cont.

LIST OF ABBREVIATIONS OF INSECTS AND DISEASES

Insects and Diseases

AP	Air pollution
AM	Armellaria mellea
ARR	Annosus root rot
BB	Bark beetles (general)
BSNB	Brown-spot needle blight
BTB	Black Turpentine beetle
BWA	Balsam woolly aphid
CB	Chestnut blight
CFD	Conifer foliage diseases
CSI	Cottonwood & Sycamore insects
CSD	Cottonwood & Sycamore diseases
CW	Carpenter worms
DDD	Dieback-decline diseases
DED	Dutch elm disease
DFB	Douglas-fir beetle
DFTM	Douglas-fir tussock moth
DM	Dwarf mistletoe
DT	Drywood termite
EPN	Elm phloem necrosis
ES	Elm spanworm
FC	Fall cankerworm
FE	Fir engraver
FR	Fusiform rust
FTC	Forest tent caterpillar
G	General
GM	Gypsy moth
HD	Hardwood diseases
HI	Hardwood insects
HS&C	Hardwood seed & cone insects
IPS	*Ips* spp.
LC	Larch casebearer
LS	Larch sawfly
LNM	Lodgepole needleminer
LOD	Live oak decline
MCB	Maple cambium borer
MPB	Mountain pine beetle
ND	Nursery diseases
NPTM	Nantucket pine tip moth
NS	*Neodiprion* sawflies
OB	Oak borers
OD	Ohia decline
OW	Oak wilt
PD	Plantation diseases
PI	Plantation insects
PC	Pitch canker
PL	Pine looper
PLI	Poplar insects
PW	Pales weevil
PWB	Pine webworm
RLI	Rangeland insects
RP	Root pathogens (general)
SECI	Seed and cone insects
SECD	Spruce beetle
SBD	Spruce budworm
SC	Scleroderris canker
SPB	Southern pine beetle
SSW	Sitka spruce weevil
ST	Subterranean termite
SWPTM	Southwestern pine tip moth
WDB	Wood-destroying beetles
WPB	Western pine beetle
WPBR	White pine blister rust
WDF	Wood-destroying fungi
WPW	White pine weevil
WSBD	Western spruce budworm
MY	Mychorrhizae

7.3 Pilot and Demonstration Projects

New pest management strategies and IPM systems are being refined and evaluated for efficacy and cost-effectiveness in pilot projects. Successfully tested strategies may then gain general acceptance from Federal, State, and private forest landowners in a demonstration area. Examples of recent pilot projects are summarized below. These projects are still in their early stages of development; consequently, to evaluate their overall effectiveness would be premature.

Colorado Front Range Vegetative Management Pilot Project. The first phase of the Front Range project was a cooperative effort by the City of Boulder, Boulder County, the Colorado State Forest Service, and the USDA-Forest Service (USDA-Forest Service n.d.) to apply intensive forest management activities to 54,000 acres of private and public lands in Boulder County, Colorado. The goals of the project were: 1) to establish vigorous, mountain pine beetle-resistant ponderosa pine stands, 2) to demonstrate research results on a pilot scale, 3) to remove fire fuels to a level that reduced the probability of large wildfires, 4) to provide suitable habitat for the needs of a variety of wildlife, and 5) to restore scenic quality to the recreational aspects of the Front Range.

Several management strategies were applied in accordance with the site conditions and management objectives. Those strategies included: 1) thinning to reduce stand density; 2) cutting and chemically treating or removing infested trees; 3) reducing fuel for forest fires i.e., old beetle-killed trees; and 4) planting trees or browse plants for wildlife. By using site-specific techniques in different locations, forest managers showed that the several alternative strategies could be employed to more effectively respond to each unique situation.

This project marks one of the first instances in which FI&DM funds were used for preventative thinning purposes. New wood utilization markets developed as part of the project, thus improving the economic feasibility of the intensive salvage and thinning operations. Other areas in the Front Range will be subject to similar treatments in later phases of the project.

Gypsy Moth Retardation Pilot Project. The GMRPP is part of a five-year, Northeast-wide gypsy moth management program that is being conducted cooperatively by the USDA-Animal and Plant Health Inspection Service (APHIS), the USDA-Forest Service, the USDA-Science and Education Administration (SEA), and several states (Ekess 1979). Established in 1979, the Pennsylvania project covers about 48,000 acres of forest land in south-central Pennsylvania along the Appalachian ridge system. The objectives of the pilot project are to: 1) demonstrate techniques in a strategy

to retard the natural spread of the gypsy moth to an average of 5 to 10 miles per year over a five-year period along selected ridges in the Appalachian Mountain system in south-central Pennsylvania; 2) evaluate biological-type insecticides on low density populations of gypsy moth in order to provide preliminary information for future use in gypsy moth population management; and 3) evaluate the effect of intervention activities on gypsy moth parasite populations in the pilot project area.

Much of the technology developed in the Accelerated Gypsy Moth R&D program is being utilized. For instance, treatments have included the application of *Bacillus thuringiensis*, nucleopolyhedrosis virus, Dimilin, and Disparlure (see Sections 6.1 and 6.2). While treatment responsibilities belong to APHIS, the USDA-Forest Service is responsible for monitoring and evaluating the subsequent treatment effects on the gypsy moth and non-target organisms.

The Green Woods Project: Integration of Targeted Harvesting of Balsam Fir with Precision Direct Protection of Fir-Spruce Forests from Spruce Budworm. The Green Woods Project is a cooperative effort between the USDA-Forest Service and the University of Maine at Orono that is funded through the CANUSA program. Goals of the program are to: 1) reduce the amount and cost of chemical suppression; 2) minimize the risk of loss by reducing balsam fir in vulnerable sizes and lowering future short-term susceptibility; 3) reduce budworm damage to tolerable levels; 4) gain wider acceptance of existing or newly developed forest protection techniques; and 5) disseminate the concepts and technology of protection forestry to resource managers through their involvement in the development of integrated protection plans (Dimond et al 1979).

Methods to achieve these goals include: 1) precision chemical treatment on a stand-by-stand basis; 2) targeted protection, i.e., chemically treat only those stands classified as high risk areas; 3) selective application of *Bacillus thuringiensis*, and 4) selective harvest of balsam fir.

Federal Dutch Elm Disease Control Project: The Dutch Elm disease (DED) project is being implemented in numerous cities throughout the country where DED is threatening the local elm population. The goal of this project is to "demonstrate how Dutch elm disease within an urban environment can be suppressed long enough to develop an economical and orderly transition from the predominant elm forest to mixed stands of shade trees" (Minnesota Department of Natural Resources 1979). The components of this disease prevention program are: intensive survey techniques, sanitation salvage, pruning, root graft barrier installations, and treatment of diseased trees with a systemic fungicide.

During the first year of operation, the overall disease infection rate decreased by about 25 percent within the project boundaries. Public involvement was excellent and four participating cities have now hired urban foresters to carry out future DED management responsibilities (Hastings 1980, personal communication).

In the absence of pilot and demonstration projects, many more of the promising pest management strategies that have recently been developed would probably still be untested, unrefined, and unaccepted.

SUMMARY

Forest pest management theory is based upon principles developed primarily for use in agricultural situations. However, the greater social, biological, legal and economic complexities involved in forestry necessitate that the standard concept of integrated pest management, as developed in agriculture, be considerably expanded to meet the needs of forest pest managers.

Consequently, an "IPM systems approach" has been developed and currently provides the basis for pest research and future management operations in the USDA-Forest Service. Specific pest management systems have been developed or are close to completion for several important forest insects. However, none have been proven adequate in an operational setting to date. Accelerated R&D type programs have layed the groundwork for IPM research and have speeded the development of some systems.

Technology transfer is critical to the successful implementation of IPM systems and consequently, is currently receiving a substantial amount of emphasis in the USDA-Forest Service.

[illegible]

[illegible]

[illegible]

[illegible] classified [illegible]

[illegible]

8.0 INSECT/DISEASE MANAGEMENT ISSUES

ISSUE NUMBER 1: Integrated pest management has become official Forest Service policy. Do field personnel adequately understand the concept and share a common working definition?

IPM directives have been issued from Washington to the field, where there is considerable confusion as to how IPM differs from existing pest management practices. Accordingly, many people in the field have indicated that there is an overall lack of direction from the Washington Office.

ISSUE NUMBER 2: Do Forest Service pest management projects include: (1) thorough examination of available control alternatives, (2) comprehensive analysis of impacts, and (3) evaluations to assess project results?

Forest Service activities are frequently controlled by cost/benefit analyses and environmental assessments prior to the implementation of the project. Few post-project evaluations are made in either the economic or environmental monitoring areas. Post-treatment evaluations should be conducted both as a means of documenting what actually happened during and after the project, and as a way to improve the information on which future projects are planned.

Program activities, such as administration and overhead, are seldom evaluated in an economic effectiveness context. Accordingly, it is often difficult to ascertain the true costs of a project because many of these costs are not specified in program budgets.

ISSUE NUMBER 3: The Forest Service is currently developing and implementing alternative pest management strategies, such as the use of: 1) selective, non-persistent pesticides, 2) behavioral modifying chemicals, 3) microbials, 4) parasites and predators, and 5) silvicultural manipulation. Is the present progress in research and implementation on these and other methods adequate?

Considerable research effort and monetary support are needed to develop alternative management strategies. Since it is often basic research, probabilities are smaller that specific results applicable to insect and disease management will become available soon. Nevertheless, institutional constraints which limit the use of conventional techniques also make the need for development alternatives more severe.

Screening, field testing, and registering selective, non-persistent pesticides, behavioral modifying chemicals and microbials is often left to the USDA-Forest Service, since these chemicals and biologicals offer little economic incentive to industry. The process is time-consuming and costly, especially when large scale pilot projects must be undertaken to develop efficacy data.

Research on silvicultural management strategies involves a commitment to continue observations on the effects of stand treatment for years or even decades after a treatment is undertaken. This commitment is a relatively recent Forest Service undertaking and must withstand future changes in priorities within the agency.

Development of conventional biological control strategies, e.g., introduction and/or augmentation of parasites and predators, also requires a long term commitment. The results of numerous natural enemy introductions were never evaluated after project monies were dissipated. Both silvicultural and biological methods of pest management act in an unspectacular way. Consequently, their beneficial effects often go unobserved.

ISSUE NUMBER 4: <u>Can project decisions be traced to agency goals and objectives?</u>

The Resources Planning Act and the National Forest Management Act require the Forest Service to prepare periodic inventories and assessments of the resources, i.e., timber, range, wildlife, recreation, minerals, and water, on the National Forest System lands. Future, potential resource outputs are projected and compared to historical supply/demand data to indicate the need for these products. Projections can then be used to determine resource output, or products, that the National Forest should provide, and to establish target levels of outputs for the resources.

Output goals are set for all lands in the National Forest System. The goals are hierarchically structured with National, Regional, Forest, and District targets. This issue asks if the decision of a District Ranger to undertake (or not undertake) a particular project can be put in the perspective of the District's annual targets. Furthermore, can this project be shown to contribute to the overall targets of the Forest, Region, and the National Forest System?

ISSUE NUMBER 5: <u>Is the Forest Service public involvement effort, with regards to pest management, providing the public with adequate information and is the agency responsive to public concerns?</u>

In order to resolve conflicts, the Forest Service must be able to not only present its concerns eloquently, but also demonstrate that it understands, and is responsive to public concerns. On the one hand, the Forest Service faces a large task in distilling all the applicable knowledge developed by research and all the experience from management into a form which the public, without prior background in forestry, entomology, and/or pathology can comprehend. By the same token, the public expects the Forest Service to lend an attentive ear to their concerns, and are quick to point out instances in which this did not seem to occur. Faced with individuals firmly entrenched in diametrically opposed positions, the Forest Service is expected to carry out a solution which is harmony with all desires.

ISSUE NUMBER 6: Is the USDA-Forest Service efficiently organized to handle insect and disease management problems?

FI&DM is organized in the State and Private Deputy Area and serves State and private forestry, National Forest System and other Federal lands. Many Forest Service personnel in the National Forest System feel that FI&DM would be more efficient if located in that branch. However, that would have some disadvantages too, since it could impair FI&DM's efforts to institute major programs which require support from State and Private forestry as well as the National Forest System.

Further, FI&DM staff are often centrally-located at the Regional or Area offices. It has been suggested that more field offices be established nearer their respective National Forests so as to facilitate their everyday interactions with forest management personnel and the effective transfer of pest management technology.

ISSUE NUMBER 7: Are pest management communications and cooperation between the Forest Service and other areas of Government adequate?

In order to fulfill its pest management role, the Forest Service is required to interact with other government agencies, departments, and at several levels within the Department of Agriculture, to which it belongs. These interactions involve a wide array of subjects, including: (1) technology transfer with other agencies that have similar missions; (2) input into developing regulatory processes; (3) providing data to agencies or groups whose responsibility it is to oversee Forest Service activities and 4) providing technical expertise and financial assistance to all Federal land managing agencies which have pest problems.

In some instances, adversary relationships can develop between agencies simply because the mission, and therefore the perspective, of the Forest Service is different from that of the other agency(ies). Potential exists for these adversary relationships to be productive, or self-defeating. An adversary relationship can be productive when it serves to insure that all relevant information is considered prior to making any decision, and minimizing any innate biases which could occur if only one agency or group served as the decisionmaker. However, if the opinions of all groups are polarized and unyielding, the adversary process often serves to either stagnate the decision process, or to create ill-will which is carried over into all future relationships between the groups. The skill to which the USDA-Forest Service is able to balance presentation of its own needs to fulfill its mission with the flexibility needed to accomplish the goals of interagency relationships will therefore not only be a factor in any one decision, but might play a role in future interactions between these same areas of government.

ISSUE NUMBER 8: Do adequate mechanisms exist to provide detailed exchange between Forest Service research, university researchers, and forest managers?

Communication between these groups could serve a multitude of purposes, including (a) insuring that research in the Forest Service is not duplicated by university or private research; (b) making managers aware of the latest state-of-the-art developments; (c) informing researchers of management's need for improved information and techniques; and (d) developing presentation methods for research results which are understandable at the management level. A long-standing complaint of many mangers is that research does not provide the guidance they need, within a reasonable time frame, to conduct adequate day-to-day resource management activities. On the other hand, researchers often note that studies proposed by managers have already been completed.

ISSUE NUMBER 9: Do Forest Service data systems provide decision makers with adequate information?

Line officers at all levels of the Forest Service need adequate information not only to base their decisions on strong scientific evidence, but also to document their reasoning for any pest management decision. If this information does exist or can be collected, but is not used, the Forest Service may be subjected to severe criticism from other Federal agencies and the public. In order to be useable, data must be comprehensive, but presented in an understandable manner. Data collection must be sensitive enough to provide the needed information and data management methods and presentation must be sophisticated enough to provide line officers with comprehensible and manageable information.

Data management problems can occur at all levels of the Forest Service. In the Washington Office, for example, there may or may not be a need to examine how present policies affect Regional, Forest, and District line officers' choices between various alternatives of insect, disease, or weed control alternatives. CNA found, however, that the use of various methods could not be compared at the national level. The only control method quantified is pesticide use, through FI&DM. This information has not proved comparable to the general data collected by other staff groups.

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APPENDIX TABLE 1. Scientific names for some important forest insects and diseases.

Insects	
Western spruce budworm	*Choristoneura fumiferana* (Clem.)
Spruce budworm	*C. occidentalis* Freeman
Douglas-fir tussock moth	*Orgyia pseudotsugata* (McDunnough)
Gypsy moth	*Lymantria dispar* (L.)
Larch casebearer	*Coleophora laricella* (Hbn.)
Lodgepole needleminer	*Coleotechnites milleri* (Busck)
Forest tent caterpillar	*Malacosma disstria* (Hbn.)
Shoot and tip moths	*Rhyaciona* sp.
White pine weevil	*Pissodes strobi* (Peck)
Pales weevil	*Hylobius pales* (Hbst.)
Mountain pine beetle	*Dendroctonus ponderosae* Hopkins
Southern pine beetle	*D. frontalis* Zimm.
Douglas-fir beetle	*D. pseudotsugae* Hopkins
Spruce beetle	*D. rufipennis* (Kby.)
Pine engravers	*Ips* sp.
Fir engravers	*Scolytus* sp.
Balsam woolly aphid	*Aldelges piceae* (Ratzeburg)
Diseases	
Dwarf mistletoes	*Arceuthobium* spp.
Eastern gall rust	*Cronartium quercuum* (Berk.) Miyabe ex. Shirai f. sp. *echinota*
Fusiform rust	*C. quercuum* (Berk.) Miyabe ex Shirai f. sp. *fusiforme*
White pine blister rust	*C. ribicola* Fisch.
Comandra blister rust	*C. comandrae* Pk.
Western gall rust	*Peridermium harknessii* P.
Annosus root rot	*Heterobasidion annosus* (Fr.) Bref.
Laminated root rot	*Phellinus weirii* (Murr.) Gilbertson
Black stain root disease	*Verticicladiella wagnerii* Kend.
Littleleaf disease	*Phytophtora cinnamomi* Rands
Oak wilt	*Ceratocystis fagacearum* Bretz
Brown spot needle blight	*Scirrhia acicola* (Dearn.) Sigg.
Lophodermium needle blight	*Lophodermium piniastri* Schrad and Hook
Elytroderma needle blight	*Elytroderma deformans* (Weir) Dark
Beech bark disease	*Nectria coccinea var faginata* L. W. and H.
Dutch elm disease	*Ceratocystis ulmi* (Buism.), C. Mor.
Chestnut blight	*Endothia parasitica* (Murr.) P. J.& H. W. And.
Pitch canker	*Fusarium moniliforme* var subglutinans Wr & Reink
Scleroderris canker	*Gremmeniella abietina* (Lagberg.) Morelef
Hypoxylon canker	*Hypoxylon mammatum* (Wanl) Miller

APPENDIX TABLE 2. A regional list of some important forest insects.

USDA-FS Regions / Insect Species	WSBD	SBD	DFTM	GM	LC	LNM	FTC[1]	MHD[1]	S&TM[1]	WPW	PRCW	WPB	MPB	SPB	DFB	SB	PE	FE	BWA	HB	C&S[1]
1	O		O		O		O	O	O			O	O		O	O	O		O		O
2	O						O	O	O			O	O		O	O	O	O			O
3	O		O				O	O	O			O	O		O	O	O				O
4	O		O				O	O	O			O	O		O	O	O				O
5			O			O	O	O	O			O	O		O		O	O			O
6	O		O		O		O	O	O			O	O		O	O	O	O	O		O
8				O			O	O	O		O			O			O		O	O	O
9		O		O			O	O	O	O	O								O	O	O
10																					O

WSBD - Western spruce budworm
SBD - Spruce budworm
DFTM - Douglas-fir tussock moth
GM - Gypsy moth
LC - Larch casebearer
LNM - Lodgepole needleminer
FTC - Forest tent caterpillar
MHD - Misc. hardwood defoliaters
S&TM - Shoot and tip moths

WPW - White pine weevil
PRCW - Pine root collar weevil
WPB - Western pine beetle
MPB - Mountain pine beetle
SPB - Southern pine beetle
DFB - Douglas-fir beetle
SB - Spruce beetle
PE - Pine engravers
FE - Fir engravers
BWA - Balsam woolly aphid

HB - Hardwood borers
C&S- Cone & seed insects

[1]Of local importance only

APPENDIX TABLE 3. A regional list of some important forests diseases.

Regions \ Diseases	DM	WGR	EGR	FR	WPBR	CBR	ARR	AMR	LRR	LL	BSRD	OW	PC	SC	BSNB	ENG	BBD	DED	EPN	CB	DY	ND [1]	S&C [1]
1	O	O			O	O	O	O	O		O										O	O	O
2	O	O				O	O	O			O							O			O	O	O
3	O	O					O	O													O	O	O
4	O	O			O	O	O	O	O		O							O			O	O	O
5	O	O			O		O	O			O					O		O[1]			O	O	O
6	O	O			O	O	O	O	O		O					O		O			O	O	O
8			O	O			O	O		O		O	O	O	O			O	O	O	O	O	O
9	O		O		O		O	O			O	O		O			O	O	O	O	O	O	O
10	O	O					O	O													O		

DM - Dwarf mistletoe
WGR - Western gall rust
EGR - Eastern gall rust
FR - Fusiform rust
WPBR - White pine blister rust
CBR - Comandra blister rust
ARR - Annosus root rot
LRR - Laminated root rot
LL - Littleleaf disease
BSRD - Black stain root disease
OW - Oak wilt
AMR - Armellaria root rot

PC - Pitch canker
SC - Scleroderris canker
BSNB - Brown spot needle blight
ENG - Elytroderma needle blight
BBD - Beech bark disease
DED - Dutch elm disease
EPN - Elm phloem necrosis
CB - Chestnut blight
DY - Decay
ND - Nursery diseases
S&C - Seed and cone diseases

[1]Of local importance only

APPENDIX TABLE A-4. Douglas-fir tussock moth research and management (or IPM) summary.

	SURVEY AND DETECTION	BIOLOGICAL EVALUATION	IMPACT EVALUATION	STAND HAZARD EVALUATION	CHEMICAL	BIOLOGICAL	SILVICULTURE
Research, Development, and Implementation Needs as of 1970	Generally adequate for high populations. Efficient methods needed to detect moths at low populations levels.	1) To improve larval sampling methods at low population levels, 2) To develop a population prediction model.	1) Methods for quantifying defoliation, 2) Methods for relating defoliation to damage, 3) A model to predict impact as a function of moth population levels.	Stand hazard-rating system needed.	1) Alternative pesticides to DDT, 2) Evaluate the potential for insect growth regulators in suppression, 3) Evaluate potential for pheromones in suppression.	Evaluate the use of microbials in suppression.	Develop silvicultural management strategies for this insect.
Work Accomplished During 1970's	Pheromone detection system developed for use in areas with low moth populations (USDA-DFTMP).	1) Larval sequential sampling techniques and a pheromone sampling system have been developed (USDA-DFTMP) 2) A population prediction model has been developed (USDA-DFTMP and MAG).	Significant progress was made in #1, 2, and 3 as part of both FI&DR and USDA-DFTMP.	Stand hazard-rating system developed (USDA-DFTMP).	1) Several new pesticides registered (USDA-DFTMP). 2) Dimilin field tested and found to be an effective control agent, 3) A pheromone suppression system developed (USDA-DFTMP).	A virus (NPV) and bacteria (BT) were registered for use (USDA-DFTMP).	The stand hazard evaluation system that has been developed points out what stand characteristics should be selected against in silvicultural management activities.
Research, Development, and Implementation Needs as of 1980	Minimal	The population prediction model needs more refining and must be tested before it can be considered to be a useful management tool.	Long-term effects of defoliation on growth loss and mortality need continued research.	Hazard-rating technology needs transferring to landowners.	Register Dimilin. Need to test pheromone suppression system under outbreak conditions.	BT is extremely expensive and has not been consistently effective - refinements are needed in these areas. NPV needs to be produced and made available in case of an outbreak in the near future.	Need to demonstrate the effectiveness of good silvicultural pest management.
Work in Progress	Fine Tuning.	Minimal	Above research is continuing at the PNW Station.	Initial stages of technology transfer have begun in Pacific Northwest.	Minimal	The search is on for a company to produce NPV. Possibly the Forest Service may produce it themselves.	Minimal
General Comments	Pheromone detection system is now in operation and should give sufficient warning as to any impending outbreaks.	It remains to be seen whether or not outbreaks can be predicted in the "real world." Success will depend on accurate sampling data being fed into an operational computer program. Perhaps if it works, the next outbreak can be suppressed in its initial stages before signifi-	Impact studies and stand hazard evaluations have helped define what types of stands do not incur outbreaks. This information may help reduce the acreage needing spraying during the next outbreak.	This system can be an extremely valuable management tool if insect monitoring efforts are, indeed, given high priority in high hazard areas.	Although the USDA-DFTMP program was considered a great success, its value won't really be known until the next outbreak occurs. Will the new insecticides and pheromones be effectively utilized?	If an outbreak occurred next spring, conventional pesticides would probably be used since Dimilin isn't registered, BT is too expensive and erratic and there is no stockpile of NPV to use.	Technology transfer is extremely important here. Silvicultural guidelines for USDA-DFTMP need to be integrated into long-range forest planning. Such integration was only begun in late 1979.

APPENDIX TABLE A-5. Eastern spruce budworm research and management summary.

	SURVEY AND DETECTION	BIOLOGICAL EVALUATION	IMPACT EVALUATION	STAND HAZARD EVALUATION	CHEMICAL	BIOLOGICAL	SILVICULTURAL
Research, Development, & Implementation Needs as of 1970	Generally adequate	1) Efficient methods of sampling insects at low population levels	1) Methods for quantifying defoliation , 2) Methods for relating defoliation to damage, 3) Methods for relating damage to socio-economic impacts	Stand hazard rating systems needed refinement	1) Alternative chemicals to DDT and better application technology, 2) To evaluate the potential of insect growth regulators in suppression, 3) To evaluate the potential for pheromones in suppression	1) To evaluate the use of microbials in suppression	1) Needed to develop silvicultural management strategies for this insect. 2) Utilization guidelines needed for budworm-killed timber.
Work Accomplished During 1970's	----	Minimal[1]	Minimal	Some preliminary work done at NC Exp. Stn.[1]	1) Have registered acephate and trichlorfon, 2) None[1], 3) None[1]	Some preliminary work on BT was carried out. However, cost-effective operational procedures have not been developed	Minimal efforts
Research, Development, & Implementation Needs as of 1980	----	Same as above	Same as above	Same as above	1) Applicator technology still needs great improvement to increase treatment efficacy and to reduce spray drift, 2), 3); Same as above	Need to increase efficacy and decrease cost of BT treatments.	Same as above
Work in Progress	----	Development of a system utilizing pheromones and light traps (CANUSA). Refinements of larval sampling systems (CANUSA).	Some research and administrative studies on techniques for forest damage assessment (CANUSA & FI&DM,NA)	Minimal	Improvements in application technology and spray strategies are being developed through CANUSA. The potential for Dimilin & other IGR'S as suppressants is being investigated through CANUSA, however, no work is being funded for pheromone suppression	Extensive work in BT research & development is currently funded through CANUSA	Projects demonstrating the effectiveness of silvicultural manage-are being funded through CANUSA. Utilization guidelines for budworm-killed timber being developed (CANUSA).
General Comments	----	----	Maine's 1980 budworm spray program could not be justified in economic terms because future wood supply and demand data was not available. Do these stands need protection? (USDA-Forest, 1980).	Has been identified as high priority research by CANUSA personel.	Pheromone suppression has excellent potential, and yet is not being investigated through CANUSA-East.	Presently, BT is only applied on a very limited basis to protect very high value resources in environmentally sensitive areas	Silvicultural management probably has greater potential for long-term budworm management than any other strategy

[1]Relevant research has been conducted in Canada, however, no opera-tional procedures have been developed.

APPENDIX TABLE A-6. Mountain pine beetle research and management summary.

	SURVEY AND DETECTION	BIOLOGICAL EVALUATION	IMPACT EVALUATION	STAND HAZARD EVALUATION	CHEMICAL	BIOLOGICAL	SILVICULTURAL
Research, Development, and Implementation Needs as of 1970	Generally adequate	Population prediction model	1) Methods for quantifying mortality; 2) Model for projecting impact over entire rotation 3) Region-wide loss assessments.	Stand hazard-rating system	Conventional chemicals available to effectively kill beetles however, prophylactic sprays needed to protect high value trees.	None	Silvicultural guidelines needed for beetle management.
Work Accomplished During 1970's	----	Model developed at INT Station and is operational for Regions 1, 2, and 4.	Multi-stage sampling techniques developed to efficiently quantify mortality (MAG, Regions 1 & 2). MAG has played large role here. Population prediction model has been linked to Stage's Stand prognosis model & is capable of predicting future impacts (INT Station).	Hazard-rating system developed at INT Station, FI&DR	Prophylactic sprays developed through INT Station, FI&DR.	----	Guidelines developed at INT Station, FI&DR.
Research, Developement, & Implementation Needs as of 1980	----	Model needs refining, testing, and modification for use in Region 6.	Region-wide loss assessments still needed	----	----	----	1) effectiveness of guidelines need to be demonstrated; 2) stands need to be brought under intensive management.
Work in Progress	----	Model being refined at INT Station	Loss assessment data are currently being obtained in several western regions.	----	----	----	Pilot projects to demonstrate effectiveness in progress in Regions 1 & 2.
General Comments	----	----	Loss assessment data are needed to compare losses in managed vs. unmanaged stands in order to justify silvicultural management activities that are done primarily for this insect.	Probably the most important work accomplished for this insect.	Chemicals alone cannot effectively manage this insect. There are no area-wide treatments available.	Biological control methods hold little promise in bark beetle management.	Greatest management potential is in silviculture, but treating the vast acreages of overmature, overstocked stands would be an overwhelming task.

APPENDIX TABLE A-7. Southern pine beetle research and management summary.

	SURVEY AND DETECTION	BIOLOGICAL EVALUATION	IMPACT EVALUATION	STAND HAZARD EVALUATION	CHEMICAL	BIOLOGICAL	SILVICULTURAL
Research, Development, & Implementation Needs as of 1970	Generally adequate 1) Improved aerial survey technology 2) Techniques to detect pre-visual populations.	1) Better methods of sampling within-trees and within-infestation populations; 2) spot growth models. 3) area-wide growth models.	1) Methods for quantifying and predicting mortality. 2) Methods for determining socio-economic impact of mortality.	Stand hazard rating systems	1) To develop pesticide alternatives to Lindane; 2) Prophylactic sprays 3) To evaluate the usefulness of pheromones as suppression tools.	None	1) Needed to develop and implement silvicultural management strategies for this insect. 2) Utilization guidelines for beetle-killed timber.
Work Accomplished During 1970's	Loran-C radio navigation system improves S&D accuracy (ESPBRAP)	#1 above has been accomplished (ESPBRAP).	1) Sophisticated aerial impact survey technology developed (ESPBRAP) 2) Damage prediction models developed (ESPBRAP)	1) Considerable progress made in identification of hazardous site, tree, and stand conditions (ESPBRAP) 2) Models for ranking stand susceptibility being developed (ESBPRAP)	1), 2) Efficacy determined for 3 alternatives to Lindane and 2 prophylactic sprays (ESPBRAP). One pesticide has been registered (Dursban). 3) Basic pheromone research conducted (ESPBRAP)	----	1) See "stand hazard evaluation". These guidelines can be utilized in silvicultural management activities. 2) Utilization guidelines developed for beetle-killed timber. (ESPBRAP)
Research, Development, & Implementation Needs as of 1980	Pre-visual population detection system	Spot growth model not yet completed to operational standards. Area-wide growth models are non-existent.	1) Put models into operation	Complete stand hazard ranking models	1) Seek additional registrations on promising compounds 2) Continue pheromone research	----	1) Need practical demonstration of silvicultural management techniques. 2) Transfer utilization guidelines to user.
Work in Progress	Minimal	Research is continuing on spot growth models.	Models being installed in FS computer (ESPBRAP)	Development of stand hazard ranking models (ESBRAP)	Sumithion should be registered in near future (ESPBRAP)	----	1) Thinning studies are ongoing in Mississippi and Texas (ESPBRAP) 2) Some transfer of utilization guidelines is being accomplished (ESPBRAP)
General Comments	Current S&D technology was unable to detect initial stages of the 1979 outbreak.	———	Impact estimate technology more advanced than for most other major forest insect pests.	The rating system is regarded as very valuable and will provide a "backbone" for many silviculture management decisions.	New pesticides will provide land managers with more pest control flexibility and is a necessary part of any IPM program. Pheromone-induced suppression strategies have shown only limited potential.	Biological control methods have little promise in bark beetle management.	Stands identified as high hazard areas must be treated and little of this is currently being done. Technology transfer is a key here.

APPENDIX TABLE A-8. Dwarf mistletoe research and management summary.

	SURVEY AND DETECTION	BIOLOGICAL EVALUATION	IMPACT EVALUATION	STAND HAZARD EVALUATION	CHEMICAL	BIOLOGICAL	SILVICULTURAL
Research, Development, & Implementation Needs as of 1970	Generally adequate	Incorporate mistletoe rating activities into stand inventory processes.	1) Methods for relating infection intensity to growth loss 2) Models for projecting dwarf mistletoe impact over an entire rotation.	——	Chemical control options for mistletoe management.	Biological control options for dwarf mistletoe	Silvicultural guidelines needed for dwarf mistletoe management.
Work Accomplished During 1970's	----	Some incorporation of rating activities into stand inventory processes, especially in Region 6	1) Infection intensity-impact relationships have been developed sufficiently for most commercial timber species. 2) Models have been developed for pure stands of ponderosa and lodgepole pine	——	Sporadic research without significant accomplishment.	Sporadic research without significant accomplishments.	Adequate silvicultural guidelines have been developed for dwarf mistletoe infecting several important western conifers.
Research, Development, & Implementation Needs as of 1980	----	Same as above.	1) Although the basics have been developed for DM impact assessments, quantitative differences among host/mistletoe combinations, stand types, and geographic areas are needed to establish rate functions for prediction models. 2) Prediction models are needed for mixed and pure stands of other species such as Douglas-fir.	——	Same as above.	Same as above.	1) Develop silvicultural management guidelines for additional conifer species. 2) Effects of thinning on dwarf mistletoe infection intensity in residual stands needs to be evaluated. Such data would provide valuable input into stand prediction models. (Hawksworth 1979, personal communication).
Work in Progress	----	MAG is continuing to coordinate mistletoe evaluation with stand inventory activities	Impact projection models are being developed for mixed stands at the INT Station.	——	Some work in this area underway at the PNW Station.	None	Thinning studies are just getting underway at the INT Station.(Hawksworth 1979, personal communication).
General Comments	----	Incorporation of infection intensity data into stand inventories would greatly facilitate mistletoe impact assessments & long-range management planning with impact prediction models.	Generally,state of the art in dwarf mistletoe impact assessment is satisfactory for only a few timber species. Yield formulation models are widely utilized for both lodgepole and southwestern ponderosa pine.	Mistletoe hazard in a stand is usually readily apparent. If no mistletoe exists in a stand at present, future hazard would be minimal regardless of site and stand factors.Consequently, a hazard rating system in the usual sense is unnecessary.	Chemical control options for dwarf mistletoe would be very expensive if they were ever developed and would only be worthwhile in areas where cost would not be a consideration, i.e., recreation area.	Neither the need nor the potential for biocontrol of dwarf mistletoe has been established.	Silvicultural management strategies are very well developed for many important conifers. However, the knowledge does nothing to improve conditions on vast acreages of unmanaged forests in the west.

APPENDIX TABLE A-9. Root diseases of western conifers research and management summary.

	SURVEY AND DETECTION	BIOLOGICAL EVALUATION	IMPACT EVALUATION	STAND HAZARD EVALUATION	CHEMICAL	BIOLOGICAL	SILVICULTURAL
Research, Development, and Implementation Needs as of 1970	1) To develop aerial survey methods for detection of root diseases over large areas; 2) To establish the distribution of root diseases on western forest.	1) To determine rates of disease spread, 2) To develop models that will predict rates of disease spread through stands (epidemiological model).	1) To develop methods that quantify root disease damage, 2) To develop models that will predict socio-economic impacts as root disease centers expand, 3) To quantify root disease impacts on a forest-wide basis.	1) To determine site and stand factors which are correlated with disease incidence, 2) To develop stand hazard prediction models based on data collected in #1.	—	—	Develop silvicultural management strategies for root diseases.
Work Accomplished During 1970's	Some methods utilizing infrared aerial photography have been developed to identify root disease centers (INT Station).	Baseline data collected for some of the important diseases, i.e., laminated root rot, armellaria root rot. No epidemiological models have been developed.	Methods have been developed utilizing infrared and color aerial photography to quantify mortality. They have been extensively utilized in the Region 5 Pest Damage Inventory.	The Pest Damage Inventory in Region 5 has been collecting data on site and stand factors associated with root disease incidence. Other work in this area has been minimal.	—	—	Minimal: Some silvicultural guidelines for black stain root disease and laminated root rot have been developed at the PSW and PNW stations respectively.
Research, Development, and Implementation Needs as of 1980	Need to refine aerial survey techniques and develop more accurate and efficient methods of diagnosing root pathogens during ground checking procedures.	Need to determine how the rate of spread varies, depending on host/root disease combinations, stand types and site factors. Then incorporate this data into an epidemiological model.	Impact prediction models still need to be developed and will depend upon the existence of suitable epidemiological models to link up with.	Same as above.	—	—	Same as above.
Work in Progress	Research to improve diagnostic methods is being funded at several universities by the USDA-Forest Service.	Some of the above data are being collected and a model developed at the INT Station.	Loss assessment surveys have been initiated in Regions 1, 4 and 6. The Pest Damage Inventory continues in Region 5.	Both #1 and 2 above are being addressed in current research at the INT Station.	—	—	Relevant research and administrative studies on important root diseases in northern Rocky Mountains are being conducted through the INT Station and FI&DM, Regions 1 and 6.
General Comments	Root diseases are probably the hardest forest pests to detect and identify. More refinement of S&D techniques are necessary to serve as a basis for impact evaluations and the planning of treatment strategies. These techniques need to be effectively utilized during stand inventory activities.	Such information is necessary to predict future impacts and much more needs to be collected.	Much more work needs to be done in this area. The impact of root diseases has been largely ignored and probably underestimated greatly in the past.	Much more work needs to be done in this area to develop an operational hazard evaluation procedure.	Chemicals are not considered to have significant potential in root disease control except in nurseries and as preventive stump treatment following thinning activities. (Parmeter 1980, personal communication).	Biological control is not considered to have significant potential in root disease management. (Parmeter 1980, personal communication).	Much more work needs to be done in this area to develop operational silvicultural management strategies.